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DoD Corrosion Prevention and Control Program

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa

Final Report on Project FAR-16 for FY06

L.D. Stephenson, Ashok Kumar, Robert Walde, and Max Merzlikin

August 2009

Construction Engineering Research Laboratory

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Final Report on Project FAR-16 for FY06

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Final report

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Abstract: The corrosion of steel rebar in reinforced concrete structures is a pervasive and expensive problem for the Department of Defense. The maintenance and repair costs for affected structures and equipment amounts to hundreds of millions of dollars each year, and the degradation negatively impacts military readiness and infrastructure safety. This report documents a demonstration of a concrete rebar corrosion inhibitor system and a liquid galvanic coating that provides cathodic protection for steel-reinforced concrete. These treatments were applied to critical infrastructure in a highly corrosive environment located at U.S. military facilities in Okinawa, specifically, two portions of a wall ring girder in a warehouse at Naha Military Port and two culvert bridges at the Kadena Air Force Base fuel storage depot.

The data obtained in this demonstration show quantitatively that the corrosion inhibitor application significantly reduced the corrosion rate of the rebar on the tested structures. The galvanic coating appears to be providing protection to the rebar, but quantifying the extent of protection or positive impact on service life would require further monitoring and evaluation.

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Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Control and Prevention Project FAR-16, “Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa” The proponent for the work was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), the stakeholder was the U.S. Army Installation Management Command (IMCOM), and the customer was U.S. Army Garrison, Okinawa. The project was funded under Military Interdepartmental Purchase Requests MIPR6FCERB1020 , dated 20Mar06; and MIPR6H6AG3CPC1, dated 15May06; and MIPR6HMBHDE097, dated 31 May 06. The technical monitors were Daniel J. Dunmire (OUSD(AT&L)Corrosion), Paul M. Volkman (IMPW-E), and David N. Purcell (DAIM-FDF).

A portion of the work was performed by Surtreat Holding project team was composed of Max Merzlikin, Tony Fiasco, Robert Walde, Peter Ault (Elzly Technical Corp., a subcontractor to Consulex), and Conclinic, Inc. Bushman & Associates provided independent technical supervision under contract to Mandaree Enterprise Corporation. The ERDC-CERL CPC Project Manager was Dr. Ashok Kumar and the Associate Project Manager was Dr. L. D. Stephenson. The following U.S. Army Garrison, Okinawa personnel are gratefully acknowledged for their support and assistance:

- Mr. Daniel Zrna, Chief Engineering, Plans and Services Branch
- Mr. John Beusse, Security, Plans and Operations Officer.

At the time this report was prepared, the Chief of the ERDC-CERL Materials and Structures Branch was Vicki L. Van Blaricum (CEERD-CF-M), the Chief of the Facilities Division was L. Michael Golish (CEERD-CF), and the Technical Director for Installations was Martin J. Savoie (CEERD-CV-ZT). The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

The Commander and Executive Director of the U.S. Army Engineer Research and Development Center was COL Richard B. Jenkins and the Director was Dr. James R. Houston.

Executive Summary

This OSD Corrosion Control and Prevention (CPC) project evaluated and demonstrated the use of two types of emerging technologies to mitigate corrosion in existing concrete structures. The first type consists of surface-applied corrosion inhibitors for steel reinforced concrete structures. The second type is a sacrificial cathodic corrosion protection coating developed by the National Aeronautics and Space Administration (NASA).

The Surtreat corrosion protection system used in this project consists of (1) an ionic-anodic type of inorganic migratory corrosion inhibitor (TPS II), (2) an organic vapor phase migratory corrosion inhibitor (TPS XII), and (3) a reactive silicone surface protection agent (TPS XVII). The combined application of these three corrosion-inhibiting formulations provides a durable and multifunctional corrosion-inhibiting environment along with a reduction in water penetration rate. The cathodic coating system consists of an inorganic silicate vehicle containing zinc, aluminum, magnesium, and indium metal powders. The coating is applied to a reinforced concrete surface along with titanium mesh strips that are connected to the rebar to conduct cathodic current produced by the coating.

Two culvert bridges located at the Kadena Air Force Base fuel tank farm and two wall ring girders in the northeast end of Warehouse Building 306 at the Naha Military Port were selected as the technology demonstration sites. The two bridges exhibited early signs of rebar corrosion as seen by concrete spalling in several areas, exposing rusted rebar. The two sections of wall ring girders exhibited significant signs of rebar corrosion in the form of concrete spalling and exposed rusty rebar.

The project results show that properly selected and applied migratory corrosion inhibitors or sacrificial cathodic coating systems can be successfully used to extend the life of reinforced concrete structures. These technologies demonstrated the capability of reducing measured corrosion rates. Before and after measurements indicated rates were reduced by a factor of 3.5 on culvert 2, by 2.7 on ring girder 1, and by 1.9 on ring girder 2. Water permeation rates were also significantly reduced. A return on investment of 10.29 is projected, resulting from a service life increase for the treated structures.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
mils	0.0254	millimeters
square feet	0.09290304	square meters

1 Introduction

1.1 Problem statement

The corrosion of steel rebar in reinforced concrete structures is a pervasive and expensive problem for the Department of Defense. The maintenance and repair costs for affected structures and equipment amounts to hundreds of millions of dollars each year, and the degradation negatively impacts military readiness and infrastructure safety. Despite the numerous technological advances in corrosion prevention and control in recent decades, innovative new methods are continually sought to address persistent corrosion problems for which straightforward solutions have not yet been developed.

This report documents an evaluation of two emerging corrosion prevention and control technologies: a corrosion inhibitor system for steel rebar in reinforced concrete, and a liquid-applied sacrificial galvanic coating that can provide cathodic protection for reinforcing steel. The demonstration sites for these technologies were two critical facilities located in a highly corrosive environment located at U.S. military installations in Okinawa, Japan. At one site, Building 306 at Naha Military Port, a Liquid Galvanic Coating developed by the National Aeronautics and Space Administration (NASA)[1] was applied to one portion of the building's wall ring girder in Building 306 (a warehouse); and the Surtreat rebar corrosion inhibitor system[2] was applied to another portion. At the other site, the Kadena Air Force Base (AFB) fuel storage depot (Kuwae Tank Farm), the Surtreat system was applied to two culvert bridge structures supporting a roadway.

The Surtreat corrosion inhibitor system consists of surface-applied chemical formulations known as TPS II (inorganic migratory corrosion inhibitor), TPS XII (organic vapor phase corrosion inhibitor) and XVII (reactive silicone surface protection agent). The NASA Liquid Galvanic Coating (LGC) provides cathodic protection to embedded steel reinforcement members when electrical continuity is established between the coating and the embedded steel.

[1] United States Patent 6627065, "Liquid galvanic coatings for protection of imbedded metals."

[2] Surtreat Holding LLC, Westmont, IL, 60559.

1.2 Objectives

The technology evaluation objectives of this project were to:

- demonstrate and evaluate the performance of a combination of two different types of chemical corrosion inhibitors as a corrosion inhibiting system for reinforced concrete
- demonstrate and evaluate the performance of the NASA-developed LGC as a cathodic protection technology for reinforced concrete
- show how before and after measurement of concrete chemical condition and the rate of corrosion can lead to better selection of corrosion-control processes.

The operational objectives of the project were to:

- restore and protect from corrosion two culvert bridges at the Kuwae AFB fuel depot in order to extend their useful life
- restore and protect two portions of a degraded ring girder in warehouse Building 306 at the Naha Military Port.

1.3 Approach

The two corrosion treatment technologies were applied to two culvert bridges and two ring wall girders in a warehouse in cooperation with Okinawa personnel. These structures were selected because they exhibited signs of rebar corrosion that required repair. The Surtreat corrosion inhibitor system was specified for the two culvert bridges and one of the two ring wall girders. The NASA LGC system was chosen for the other ring wall girder. The details of the approach for implementing both of the technologies are presented in Chapter 2.

Additional supplementary detail about this demonstration are provided in the following appendices:

- Appendix A: Robins AFB B-1 Beddown and Seymour Johnson Project Reports
- Appendix B: Detailed Description of Technology Application Procedure
- Appendix C: Elzly Contract Final Report
- Appendix D: Bushman & Associates Contract Report
- Appendix E: Corrosion Inhibitor Application Process and Product Data Sheets

- Appendix F: Technical Information on Galvapulse and GWT Metrics Technologies
- Appendix G: Suggested Implementation Guidance
- Appendix H: Contractor Planning and Safety Documents
- Appendix I: Project Management Plan for CPC Project FAR-16.

2 Technical Investigation

2.1 Initial assessment of concrete condition

The major cause of deterioration of reinforced concrete structures is corrosion of the reinforcing steel (rebar) and attack by acidic materials. The rebar in a new properly constructed concrete structure is protected from immediate corrosion by the alkaline (pH 13) concrete cover (about 2 inches).

The high pH acts as a natural corrosion inhibitor. With time, carbon dioxide (CO_2) and other acidic materials in the environment will penetrate the concrete and drop the pH below 11, at which point the natural corrosion inhibition is lost, and if air and water (moisture) are in contact with the rebar corrosion will take place. The process by which CO_2 decreases pH is referred to as carbonation.

Salt (chloride ions) from salt water and deicing materials penetrate concrete and migrate to the rebar level where they will accelerate corrosion. Chloride content is typically measured in lb/yd^3 or parts per million (ppm). Concrete chloride content is divided into two types, total and water-soluble. The water-soluble form is primarily responsible for the acceleration of rebar corrosion. As a rule total chloride content above 400 ppm and water soluble content above 200 ppm are considered as the levels where concern about rebar corrosion rate starts.

The first step in solving a corrosion problem is to identify the root cause, mechanism and rate. This can be done by measurement of the surrounding environment (pH and chloride concentration) visual inspection (pitting or uniform), and rate (half-cell potential, polarization resistance and coupons). Inspection to determine the amount of metal loss is also done to determine if the structure is beyond the point of being saved even if the rate of corrosion is reduced.

The presence of corrosion in the selected structures was initially determined by observing the presence of concrete spalls and corroded rebar. The following properties were tested to evaluate the status of the rebar corrosion rate and cause of corrosion before treatment. Further details on the tests and analysis of the data performed by Elzly Technical Corp. are

contained in Appendix C. Testing of the culverts and ring girder were also performed before and after application of the treatments by Bushman & Associates. Their data and analysis are presented in Appendix D.

- pH of cement at the rebar level
- total and water-soluble chloride content in cement at the rebar level
- corrosion current and rate measured in micrometers of steel loss per year (to calculate an average corrosion rate)
- half cell potential
- concrete resistance or conductivity

The concrete pH at the rebar level was found to be reduced from 13 to 11 owing to penetration of atmospheric CO_2 and other acidic materials in the environment (i.e., carbonation). The total chloride content of the concrete surrounding the rebar on all structures was measured and found to be less then 50 parts per million (ppm). The rebar corrosion rate was measured using a Galvapulse instrument, which measures the corrosion rate of steel rebar using galvanic current. The corrosion rate was found to be elevated only when the concrete was wet.

These analytical results demonstrated that the corrosion was due to the reduction in concrete pH below the point where it will inhibit rebar corrosion, and that it was primarily taking place when the concrete was wet or damp due to rain or high humidity. Chloride content was not found to be a factor in the corrosion. These results indicated that inhibitors of both the anodic and cathodic types would work on these structures.

One structure selected for demonstration of the technologies was Building 306, a warehouse located at Naha Military Port. Two equal-size portions of a ring girder in area A of the building were designated for treatment, positioned on opposite sides of the darker column shown near the center of Figure 2.1. Side 1 was designated for application of the Surtreat corrosion inhibitor system, and side 2 was designated for application of the NASA-developed LGC. Figure 2.2 shows the condition of side 2 of the ring girder before treatment.

The other structures selected were two culverts supporting a vehicle roadway at the Kuwae tank farm. Culvert 2 is shown in Figure 2.3 and culvert 3 is shown in Figure 2.4

Figure 2.1. Building 306 warehouse, inside ring girder, side 1 (left) and side 2 (right).

Figure 2.2. Building 306 warehouse, northeast wall, inside ring girder side 2.

Figure 2.3. Tank farm culvert 2, all concrete surfaces.

Figure 2.4. Tank farm culvert 3, vertical concrete support components.

2.2 Demonstration structure surface preparation

2.2.1 Building 306, section A ring girder, sides 1 and 2

As the deterioration process had been an ongoing problem within the structural components and the walls of Building 306 several attempts at repair had previously been made. These included concrete patching, coating and painting. To produce a workable surface for the Surtreat system and the LGC, previous repair materials and coatings had to be removed. The selected method was mechanical grinding using diamond abrasives and demolition of old repairs by chipping with electric chipping tools. Surface of the girder to be repaired was also sounded for signs of new delaminations. All new delamination areas were also demolished. As per concern expressed during original inspection with the members of ERDC-CERL, the paint covering the girder was also inspected for signs of lead.

The girder surface was cleaned of paint and debris, dust-free and solid with no additional delaminations sounded prior to application of the systems.

Rebar exposed during demolition was cleaned with an electric wire wheel tool to comply with the requirements for installation of a rust converter direct-contact corrosion inhibitor for steel.

To satisfy health and environmental concerns, the selected equipment had to produce the least amount of dust to accommodate the indoor location of the work areas.

2.2.2 Tank farm culverts 2 and 3

Inspection showed that application and prospective repair areas on both culverts 2 and 3 were relatively clean. Minor repairs noted on the surface of culvert 3 were judged to be new and therefore left in place. Culvert 2 had no visible repairs with only delaminated areas exposing corroded rebar. Only minor chipping was necessary to square the repair areas on culvert 2.

Rebar exposed during demolition was cleaned with an electric wire wheel tool, and a direct-contact corrosion inhibitor for steel was applied.

Both culverts had significant surface contamination from being periodically immersed in spillway water runoff. It was necessary to remove the surface contamination and miscellaneous algae growth and debris prior to application of the Surtreat corrosion-inhibitor system. Pressure washing was selected as the safest method to clean the work areas on both culverts. It was decided not to use more harshly abrasive or chemical means of surface cleaning in order to comply with the local environmental regulations.

2.3 CPC technology application

2.3.1 Building 306, ring girder side 1 (Surtreat)

Based on the pre-specification inspection results it was established that the Surtreat components should be applied as follows:

- After the demolition and cleaning, the rust converter direct-contact corrosion inhibitor was applied directly to the exposed rebar in the demolished delamination areas.
- Organic vapor phase corrosion inhibitor was applied to all demolished delamination areas, followed as necessary by water spray to help penetration and additional water cleaning when the prescribed rate was achieved.
- Inorganic migratory corrosion inhibitor followed the application of the organic vapor phase corrosion inhibitor, and was also applied to all demolished delamination areas followed as necessary by water spray to help penetration and additional water cleaning when the prescribed rate was achieved.

Additional thorough cleaning of repair areas was necessary following the organic vapor phase corrosion inhibitor and the inorganic migratory corrosion inhibitor application and before placement of the concrete repairs. Additional preparations were made with regard to extra time and equipment for this task.

Concrete repairs were made following corrosion inhibitor system application to the demolished delamination areas. Concrete mix was comprised of locally available masonry and contained a measure of polymer binder for better adhesion and strength. As the delaminated areas were fairly large (some up to 5 – 6 feet long on the girder edge), squaring and forming were necessary according to generally accepted construction practices.

Following placement of the repairs, new concrete was allowed to harden and cure sufficiently as to allow the forms to be removed. Following the removal of the form and visual inspection of the newly placed patches for quality, corrosion inhibitor system application continued. System application was performed by a combination of hand pump chemical sprayer and brush as follows:

- Organic vapor phase corrosion inhibitor was applied to the entire surface of the girder, including the repaired areas. Multiple applications were made followed by intermittent water spray to inhibit surface drying and facilitate penetration. It was necessary to clean the surface thoroughly with water prior to continuing with inorganic migratory corrosion inhibitor application.
- Inorganic migratory corrosion inhibitor followed the organic vapor phase corrosion inhibitor and was also applied to the entire surface of the girder ("old" and "new"). Multiple applications were made followed by intermittent water spray to inhibit surface drying and facilitate penetration. It was necessary to clean the surface thoroughly with water prior to continuing with application of the reactive silicone surface protection agent.
- Reactive silicone surface protection agent followed the application of the migratory and vapor phase corrosion inhibitors and was uniformly sprayed on all treated surfaces.

Surtreat system application was concluded by visually verifying that water would bead on all treated surfaces, as intended. More details of the inhibitor application process and the data sheets on the inhibitors are presented in Appendix E.

2.3.2 Building 306, ring girder side 2 (NASA LGC)

Based on the specifications provided by the coating supplier, the NASA LGC was applied to clean concrete by spraying.

Following demolition of the delaminated areas, repair areas were cleaned and patched with concrete. The concrete mix was comprised of locally available masonry and contained a measure of polymer binder for better adhesion and strength. As the delaminated areas were fairly large (some up to 5 – 6 feet long on the girder edge), squaring and forming according to generally accepted construction practices was necessary. During the re-

pairs, wires were connected to the rebar to provide electrical connection between the embedded reinforcing steel and the galvanic coating.

Following placement of the repairs new concrete was allowed to harden and cure sufficiently as to allow the forms to be removed. Following removal of the forms, a visual inspection of the patches was performed to assure that quality repairs had been made.

Before applying the coating, three titanium mesh strips were affixed to the surface of the girder with screws. The strips were run lengthwise and connected to the wires previously connected to the embedded rebar, as described above. An airless sprayer was used to apply the galvanic coating according to the manufacturer's specifications. Two coats were necessary. Additional touchup was performed by brush. Paint was continuously agitated in the container by mechanical means while spraying to prevent the settling of the metal paint components in order to ensure uniform distribution and prevent sprayer clogging.

The LGC application was finished when inspection showed that all concrete surfaces were uniformly covered.

2.3.3 Tank farm culvert 2 (Surtreat)

Based on the results of pre-specification inspection, the corrosion inhibitor system application method used for the Building 306 ring girder was judged to be appropriate for culvert 2. Therefore, the same basic procedures were used for surface preparation and application of the Surtreat system. All spraying was accomplished by a combination of an electrical pump and lance or a hand pump chemical sprayer. Caution was taken to apply materials to designated areas only and to avoid overspray or spillage in order to comply with local environmental regulations.

2.3.4 Tank farm culvert 3 (Surtreat without organic vapor phase)

The organic vapor phase was not used on culvert 3. Only the following two agents were applied.

- Inorganic migratory corrosion inhibitor was applied to all vertical support structures following water jet cleaning. Application was by spraying from a hand pump chemical sprayer.

- Reactive silicone surface protection agent followed the application of migratory corrosion inhibitors and was uniformly sprayed on all treated surfaces.

Corrosion inhibitor system application concluded with visually verifying that the desired effect of "water beading" had been achieved on all treated surfaces.

2.4 Post-application quality assurance

2.4.1 Building 306 ring girder

In addition to visual evaluation and inspection, the quality of repairs, the performance of the surface applied corrosion inhibitor system and the liquid galvanic coating was verified by specific testing.

The tests performed at Building 306 Section A Ring Girder Side 1 (Surtreat system) and 2 (LGC) were corrosion – Galvapulse ® method and water permeability (GWT method). A detailed description of how these tests are performed and interpreted is in Appendix F.

In addition to the methods described above, the performance of the LGC was evaluated by employing various electrochemical methods. These methods are described in Appendix C. (Elzly report)

2.4.2 Tank farm culvert 2

In addition to visual evaluation and inspection, the quality of repairs and the performance of the surface applied corrosion inhibitors was verified by specific testing. Corrosion rate tests were made with the Galvapulse instrument and the GWT water permeability method.

2.5 Performance monitoring

2.5.1 Application quality

Quality control was performed by the onsite Surtreat personnel, Army local support and engineering staff, Elzly Technology Corporation, representatives of ERDC-CERL, and other government agencies present during testing.

2.5.2 Corrosion-inhibiting performance

The corrosion inhibiting performance was measured relative to the effect of the treatments on the rebar corrosion rate and water permeability of the structure treated. Corrosion inhibiting performance was determined by measuring the rebar corrosion rate before and after application of the inhibitor systems. The corrosion rate was determined by measuring the corrosion current over a known area of rebar by the galvanic linear polarization method using the Galvapulse instrument. For the areas receiving the Surtreat technology, the corrosion current was measured in micro amps per centimeter squared of rebar surface ($\mu A/cm^2$) and was converted to a corrosion rate measurement in micrometers of rebar steel loss per year (μm/year). The LGC-treated parts required other techniques to determine the corrosion rate reduction, as discussed in Appendix C.

Water permeability was measured using a pressure cell attached to the surface of the concrete. The rate of water penetration was measured at 1 – 2 atmospheres of hydrostatic pressure, and is reported in units/second that can be converted into the water flux rate. After the treatment by the LGC, water permeability was not measured because the surface was effectively impermeable to fluids and the Rilem test could not be used effectively, as discussed in Appendix C.

3 Discussion

3.1 Metrics

Several tests were performed prior to establishing the proper rebar corrosion inhibitor application. These tests established the status of the concrete, rebar corrosion rate as well as the cause of the corrosion. Following application of the inhibitor and application of the LGC more tests were performed to evaluate the effectiveness of the two corrosion control techniques. The tests performed include the following:

- Galvapulse® — determines corrosion rate of rebar
- GWT(Germann's Water permeation Test) — evaluates water permeability of concrete
- Rainbow pH — determines concrete pH at the surface of concrete
- Rebound hammer — estimates compressive strength of concrete
- Rapid Chloride Test — determines chloride content of concrete
- Multimeter — used with various shunt resistances to measure the current flow from the sacrificial coating to the rebar
- Rilem Tube — used to evaluate material permeability to water
- Chloride content analysis by wet chemistry on powdered samples taken from structure.

3.2 Results

3.2.1 Building 306 ring girder

Ring girder side 1 (Surtreat)

The following average corrosion rates were measured on ring girder side 1 (Surtreat system). See Appendix C for more detail.

Before inhibitor	After inhibitor	Reduction %
61.4 μm/year	24.3μm/year	60 (82)

Based on the analysis of these results, it was surmised that the structure initially could have expected corrosion damage on nearly 70% of the structure in 2 – 10 years without treatment. Subsequent to treatment, no corrosion damage is expected in half of the structure, and the majority of the remaining structure has corrosion damage possible in 10 – 15 years. By

this analysis it seems reasonable to conclude that the inhibited treatment application has extended the service life of the structure by at least 10 years.

Water permeability change/reduction at hydrostatic pressure of 1.5 bar expressed as rate is as follows:

Before inhibitor ml/sec	After inhibitor ml/sec	Change %
0.14	0.015	89.3

This corresponds to a flux of 3.91×10^{-4} mm/s at 1.5 bar approximately an order of magnitude lower than before the inhibitor application.

Ring girder side 2

The following average corrosion rates were measured on ring girder side 2 (LGC). They were calculated, described, and graphically presented in the contractor report. See Appendix C for more detail.

Before galvanic coating	After galvanic coating	Reduction %
234.5 μm/year	190.3 μm/year	19

The sacrificial coating system interferes with the Galva Pulse measurement. It was therefore hard to quantitatively determine the impact on the corrosion rate. Tests performed with a digital multimeter and various shunt resistances indicated effective cathodic protection was occurring.

Several water transmission tests were performed before the application of the galvanic coating. As the coating forms a barrier to water, it was not deemed appropriate to repeat these measurements after the coating application. For the description and location of the original test and test area, see Appendix C.

Based on the tests performed, the data quantitatively shows that the corrosion inhibitor application has significantly reduced the corrosion of the reinforcing steel. Based on the short term data collected, it can be projected that the service life has been extended by more than 10 years.

The galvanic coating appears to be providing some protection to the reinforcing steel. Due to the difficulty in quantifying the change in corrosion rate, it is also difficult to quantify the extent to which it will extend the ser-

vice life of the structure. More can be learned through periodic surveys of its performance in the coming years.

3.2.2 Tank farm, culvert 2

The following corrosion rates were averaged from three separate test areas located on vertical support components of culvert 2. They were calculated, described, interpreted and graphically presented in the contractor report. See Appendix C for more detail.

Before inhibitor	After inhibitor	Reduction %
37.4 μM/year	13.1μM/year	65

Based on the contractor's analysis, the structure initially could have expected corrosion damage on over 50% of the structure in 2 – 10 years without treatment. Subsequent to treatment, no corrosion damage is expected on 40% of the structure, and the majority of the remaining structure has corrosion damage possible in 10 – 15 years. By this analysis it seems reasonable to conclude that the inhibited treatment application has extended the service life of the structure by at least 10 years.

Water permeability was measured successfully "before and after" at two locations on vertical support components of culvert 2:

Water permeability change/reduction at hydrostatic pressure of 1 bar expressed as rate is shown in Table 3.1

Table 3.1. Water permeability at culvert 2.

Location Area	Before inhibitor ml/sec	After inhibitor ml/sec	Change %	Corresponds to a flux of
A	0.054	0.014	74.1	3.69×10^{-4} mm/s at 1 bar.
C	0.095	0.006	93.7	1.74×10^{-4} mm/s at 1 bar.

3.3 Lessons learned

A repair method should be selected to complement the pacifying action of the corrosion inhibitor system and address the causes of the corrosion to the greatest extent feasible.

Corrosion inhibitors are generally applied to clean concrete surfaces and allowed to penetrate and dry. The allocated time and rate are usually a function of the ambient environment and manufacturers recommendations for installation of the particular brand or product. Therefore, the climate and environment the application is used in has to be considered prior to application.

Repairs are normally completed along with the inhibitor application. Therefore, the repairs need to be scheduled to coincide with application.

Other activities can occur that affect the inhibitors overall effectiveness. During this demonstration repairs were made to the concrete which used patching materials that tested as exhibiting increased corrosion rates from the original concrete.

It was difficult to use the Galvapulse method to determine the corrosion rate on the LGC coating as the titanium mesh distorted readings. Also, a short within the system also disrupted readings. Verification of the flow of a current into the girder by the cathodic system had to be made using a digital multimeter and various shunt resistances.

Rilem water tubes will not seal well to a coated surface, and it was difficult to perform the water permeability test following treatment of the structures.

During this test it was found that the locally procured patch material exhibited higher corrosion rates than the surrounding concrete. The reason for this should be investigated and evaluated to determine if the patch material is a potential problem.

During initial testing to evaluate the status of the concrete and rebar in the wall ring girders, it was found that the corrosion was related to water ingress either through the block wall or from the roof. It was suggested that if the root cause of this water ingress could be determined and corrected that alone would greatly decrease the rate of rebar corrosion that was being exhibited and would probably have applicability to other buildings in Okinawa. On a follow-up trip to Okinawa, it was ascertained that the pitch mastic on the asphalt roof had severe alligator cracking. At the west end of the roof, on the perimeter curb, just above the wall where Surtreat had identified the apparent water intrusion, the asphalt roofing had several

openings. There were a few tears and separations between the plies, where the mastic had failed. These defects would most likely be the source of water penetrating through the flashing and down along the walls, especially in a severe rain shower. The discovery of this source of water intrusion has prompted the inspection of another similar roof for the same problem and plans are being developed for remedial actions. By performing the initial testing to determine the root cause of corrosion you are performing tests that determine what the true cause of corrosion is so that it can be properly fixed. These causes could be maintenance problems, such as a roof leak, in which case the chemical corrosion inhibitors would not fix the corrosion problem by themselves. It can also lead to the identification of other maintenance or design deficiencies that apply to other structures.

4 Economic Summary

4.1 Method

Funding amounts ($K)

Funding	*Source*	*OSD*	*Service Matching*
Labor	290	300	
Materials	120	120	
Travel	40	40	
Report	30	30	
Air Force/Navy Participation	10	—	
TOTAL ($K)	490	490	

Return-On-Investment (ROI) computation method

Useful life savings (ULS) is equal to the "Net Present Value (NPV) of Benefits and Savings" calculated from the Spreadsheet shown in Appendix 1 that is based on Appendix B of OMB Circular A94.

ULS= $ 12,637K (from OMB Spreadsheet in Appendix 1. Assumptions for this calculation are also given in Appendix 1).

Project cost (PC) is shown as "Investment Required" in OMB Spreadsheet in Appendix 1; PC= $980K.

$$ROI = \frac{ULS}{PC} = \frac{\$12,637K}{\$980K} = 12.9$$

4.2 Assumptions

Alternative 1. The existing bridge will need maintenance from year 1 to year 13 at a cost of $40K to $52K. The bridge will be replaced in year 14 at a cost of $30.5M. The new bridge will utilize the galvanic protection compound described herein at a materials cost of $240K. The total cost will be $30.74M in year 14, as shown under Baseline Costs in the ROI spreadsheet (Table 4.1). Additional costs of $54K, will be incurred from year 1 to year 13 due to increased travel time and delays in fuel service operations to

which the bridge provides access, while portions of the bridge are shut down for maintenance, as shown Table 4.1 under New System Benefits/Savings.

Alternative 2. Applying the galvanic protection compound to the bridge deck to protect the rebar from corrosion at an investment of $980K, results in life extension of the bridge, as well as reduced maintenance. The galvanic protection system will require annual operation and maintenance costs of $15K, shown under *New System Costs* in the ROI Spreadsheet for years 1 to year 13. The additional costs due to bridge downtime will be avoided. After Year 14, the maintenance costs are the same, so no further analysis is needed. Comparing the two alternatives, the return-on-investment for Alternative 2 is 12.9.

Table 4.1. ROI calculation spreadsheet.

Investment Required			980,000
Return on Investment Ratio	12.89	Percent	1289%
Net Present Value of Costs and Benefits/Savings	125,363	12,762,154	12,636,792

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	40,000		15,000	54,000	14,019	87,852	73,833
2	40,000		15,000	54,000	13,101	82,100	68,999
3	45,000		15,000	54,000	12,245	80,814	68,569
4	45,000		15,000	54,000	11,444	75,527	64,084
5	46,000		15,000	54,000	10,695	71,300	60,605
6	50,000		15,000	54,000	9,995	69,295	59,301
7	50,000		15,000	54,000	9,341	64,761	55,420
8	50,000		15,000	54,000	8,730	60,528	51,798
9	50,000		15,000	54,000	8,159	56,566	48,407
10	50,000		15,000	54,000	7,625	52,863	45,239
11	50,000		15,000	54,000	7,127	49,410	42,284
12	50,000		15,000	54,000	6,660	46,176	39,516
13	52,000		15,000	54,000	6,225	43,990	37,765
14	30,740,000					11,920,972	11,920,972
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
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5 Conclusions and Recommendations

5.1 Conclusions

The data obtained during testing on this project show quantitatively that the corrosion inhibitor application significantly reduced the corrosion rate of the rebar on the tested structures. It can be projected that the service life of these structures has been extended by more than 10 years based on the short term data collected during this project.

The galvanic coating appears to be providing protection to the rebar, but a problem has arisen in obtaining exact measurements for the corrosion rate because of the short in the rebar system and the water ingress from outside roof problems. Consequently, it is difficult to quantify the extent of protection or how much the service life has been impacted. Further monitoring and evaluation should be performed to quantify the extent of protection given by this system.

The results of this project have shown how analysis to determine the root cause of a corrosion problem along with the use of migratory chemical inhibitors and galvanic sacrificial coatings can be used to increase the probability of obtaining improved corrosion control and therefore increased service life of concrete structures.

There will always be exceptions to the positive performance of any corrosion solution, such as the level of chloride content in the concrete above which present chemical inhibitors fail to work. Identifying such limitations will prevent the unsuccessful use of corrosion inhibitors.

5.2 Recommendations

5.2.1 Applicability

A standardized approach should be established for solving concrete corrosion problems encountered on structures. This would include a chemical and physical analysis to establish the root causes of the corrosion problem and the application of a combination of proven corrosion control systems. This would avoid the spending of large sums on simple repair of corrosion symptoms (delamination and spalling) and extensive and often unneces-

sary use of paints and coatings on concrete, when the root cause is commonly due to chemical problems (low pH, high chloride, etc.) that can only be solved by chemical means such as inhibitor use. Incorporating the analytical and corrosion control technologies used in this project as a standard procedure can decrease cost and increase benefit from corrosion damage remediation projects.

Continue to use the corrosion inhibitor technology to protect reinforcing steel from corrosion. Specifically, potentially high ROI projects in different environments should be identified and the corrosion inhibitors be further demonstrated to validate the impact the inhibitors have on the rebar corrosion rate and life extension of the structures. (Currently this inhibitor system does not work well on concretes containing chloride contents of above 3,000 ppm.)

5.2.2 Implementation

Recommended language for a draft Unified Facilities Guide Specification (UFGS) is presented in Appendix G.

Appendix A: Robins AFB B-1 Beddown and Seymour Johnson Project Reports

PROJECT REPORT

SURTREAT® APPLICATION

B-1 BEDDOWN CONCRETE TEST SLABS
ROBINS AIR FORCE BASE, GEORGIA

Reference: Prime Contract DAHA-09-97-C-0006
Subcontract No. C902042-L-9181

Prepared For: Bell Constructors, Inc.
1340 Lexington Ave.,
Rochester, NY 14606

Date: June 23, 1999

Contents:

I **INTRODUCTION**

Synthetic hydraulic fluid and engine oil leaking from B-1 Bombers in beddown areas react with the concrete pads and cause the concrete to become weak. Gas turbine and engine exhaust causes the concrete to fragment resulting in possible foreign object damage (FOD). Because of exhaust temperature, coatings cannot be used to protect the concrete from attack by the synthetic oils.

A concrete composition and surface treatment evaluation program is being conducted at the new B-1 base being constructed at Robins Air Force Base. The addition of silica fume and fly ash to low water cement ratio concrete mixes and the use of aluminum silicate cement based concrete are being evaluated. In addition, the application of chemical formulations developed by Surtreat Corp. to the concrete surface is being evaluated.

The **SURTREAT®** formulations used on this project are water-soluble chemically reactive penetrants identified as **SURTREAT-GPHP**, **SURTREAT-GP** and **SURTREAT-HC**. These formulations are applied to the concrete surface where they penetrate and react with the cement phase resulting in a decrease in porosity and acid reactivity, and an increase in pH and strength. The reduction in porosity and acid reactivity is critical for protecting the concrete pads from degradation due to adsorption of and reaction with synthetic oils.

Since the **SURTREAT** formulations penetrate and react with the cement and become part of the inorganic structure, there should be no loss of properties due to engine exhaust exposure.

II **Work Performed**

Two 400 sq. ft. concrete slabs identified as Test Location 3, Slab 2 and Test Location 4, Slab 2 (hereinafter referred to as

slab 3-2 and slab 4-2) were selected for the application of the **SURTREAT** formulations. These slabs are located under the B-1 engines in the parking area and have corresponding slabs identified as 3-1 and 4-1 which will not be treated and will be used as performance controls.

Work started at 12:00 PM on June 7, 1999. The surfaces of both slabs were tested for water adsorption, reaction with hydrochloric acid (HCl) and pH using a mixed indicator dye. They were both very adsorbent and reactive with HCl and had a surface pH of 5. These initial surface properties indicated that there was a definite opportunity to make improvements by the application of **SURTREAT** formulations.

Both slabs had a rough broom finish with particles of concrete attached to the surface, and were covered with construction dust. The surfaces of both slabs were scraped to remove the particles and swept to remove construction dust.

Slab 4-2 was treated first starting at 1:00 PM. The sun was out and air and surface temperature was about 90° F and the wind at 10 to 15 mph from the South. The pad was first wet down with water to cool the surface. Two gallons (2) of **SURTREAT-GPHP** were applied followed by 2 gallons of **SURTREAT-GP**. A water wet down followed this and 1.5 gallons of **SURTREAT-GP** and 1.5 gallons of water were applied once the surface had dried. This application cycle was completed at 2:00 PM. A total of 5.5 gallons of **SURTREAT** formulation was applied on day one for an application rate of 72-sq. ft. per gallon.

Slab 3-2 was cleaned and wet down with water at 3:00 PM. Five and one half gallons (5.5 gallons) of **SURTREAT-GPHP** were applied in several application cycles to the slab from 3:15 to 3:34 PM followed by a wet down with 1.5 gallons of water.

Both slabs were allowed to dry and were given a final wet down with water from the construction site water truck. This was done to flush **SURTREAT** from the surface into the concrete.

Work on both slabs was continued at 9:00 AM on June 8, 1999. The weather was hot and sunny 85° F with no wind. Slab 4-2 was given two applications of **SURTREAT-HC** (with a small amount of HP additive to enhance penetration) for a total

of 2.2 gallons. This was followed by the application of 2.5 gallons of water.

Slab 3-2 was given two applications of **SURTREAT-HC** between 10:45 and 11:00 AM for a total of 3.0 gallons. This was followed after the surface was dry with the application of 2.5 gallons of water.

Both slabs were allowed to dry and were then given two wet downs from the water truck at 1:15 PM and 2:45 PM.

In all cases the **SURTREAT** formulations were applied by pouring on the surface and spreading with a soft bristle broom. The surface was also dressed with the broom after each water wet down.

Figure 1 in the Appendix section summarize the **SURTREAT** applications and dosage rates.

III <u>Testing and Evaluation</u>

The slabs were tested and evaluated on June 9, 1999 for their ability to resist penetration of the hydraulic fluid and engine oil used in the B-l; and for reactivity with hydrochloric acid, surface hardness and pH. The fluid and oil were obtained from the base supplies. In addition to testing the **SURTREAT** test pads, we offered to apply the same test to all the other pads, which was accepted.

The tests were run by placing about 1 ml of liquid on the concrete surface and observing the resulting reaction and level of penetration. Reaction with hydrochloric acid is exhibited by the vigorous formation of foam. When there is no reaction the liquid just sits on the surface and can be blotted up without leaving a trace. Photos 1,2 and 3 show the appearance of HCI with and without reaction on the concrete surface. Photo 1 shows the instantaneous vigorous foam forming reaction with untreated concrete. Photo 2 shows the HCI drop spread out on the **SURTREAT** treated surface without any signs of reaction. Photo 3 shows an intermediate level of reaction on a **SURTREAT** treated surface.

One of the properties of the **SURTREAT** formulations is the chemical capture of chloride ions. This results in the formation of a white spot on the surface of **SURTREAT** treated concrete and may be observed on the HCI test areas.

The oils are also applied as 1 ml drops. The oils quickly wet and penetrate the surface and within one hour completely disappear from the surface. On penetration resistant concrete the drop sits on the surface and will still be present one hour later. In some cases the oil will spread out and wet the surface but will not penetrate. Photo 4 shows drops of hydraulic oil (left) and engine oil (right) which are setting on a **SURTREAT** treated surface. Photo 5 shows the same size oil drops on untreated concrete where they have wet and penetrated the surface.

The pH of concrete is another measure of its chemical condition. Fresh concrete has a pH of 12. This drops with exposure to acids in the atmosphere to pH ranges of 5-8 depending on the concrete porosity and reactivity. pH is measured using indicator dyes. Dark blue indicates an alkaline pH in the range of 12 and red indicates an acid pH in the range of 6.

Photo 6 shows the indicator dye giving a red color on an untreated concrete slab indicating an acid pH of 6. Photo 7 shows a dark blue color on a **SURTREAT** treated slab indicating a pH of l2.

The described test procedures were run on the **SURTREAT** treated and untreated test slabs. The tests were also run on all of the other test slabs to measure their performance. Figure 2 summarizes the results of the test, which were witnessed by a Bell Constructors employee.

IV Conclusions

A review of the test results reported in Figure 2 show that all slab areas with the exception of 3-2 and 4-2 gave a very vigorous reaction with hydrochloric acid, were wetted and penetrated by both engine and hydraulic oils and had a surface pH of 6. Some of the surfaces were soft and friable such as 1-2 and 2-2.

Area 3-2, which was treated with **SURTREAT** as described on Figure 1, had a very slight reaction with hydrochloric acid, a pH of 12 and resisted wetting and penetration by both engine and hydraulic oils. The surface is very hard and strong.

Area 4-2 also treated with **SURTREAT** as described in Figure 1 had a higher level of reactivity with hydrochloric acid than did Area 3-2, but was still much less reactive than all of the other areas. The surface had a pH of 12. Hydraulic oil wet and partially penetrated the surface, but engine oil was completely repelled.

These results show that concrete given the **SURTREAT** surface treatment process will have a significantly higher level of resistance to attack by synthetic oils; and considering its chemical structure should be resistant to impact from engine exhaust.

The **SURTREAT** application procedure use on pad 3-2 appears to have given a better result that that obtained on pad 4-2 and would be the recommended procedure. The amount of water placed on the concrete between **SURTREAT** applications could vary, depending on the ambient conditions.

FIGURE 1 SUMMARY OF SURTREAT APPLICATIONS TO SLAB 4-2 AND 3-2

DATE	TIME	GALLONS WATER	SLAB 4-2 GPHP	GP	HC	TOTAL SURTREAT	Application Rate Sq. Ft. per Gal.
6/7/99	13:00	2					
	13:30		2			2	200
	14:00			2		4	100
	14:30	2					
	15:00			1.5		5.5	72
	15:30	1.5					
	16:00	2					
6/8/99	11:00				2.2	7.7	52
	11:30	2.5					
	14:00	2.5					
	14:30	2.5					
			SLAB 3-2				
6/7/99	15:00	2					
	15:30		5.5			5.5	72
	15:45	1.5					
	16:00	2					
6/8/99	11:00				3	8.5	47
	12:00	2.5					
	14:00	2.5					
	15:00	2.5					

FIGURE 2 EVALUATION OF ROBINS AFB B-1 BEDDOWN CONCRETE

TEST LOCATION	SLAB DESIGN.	MATERIAL DESCRIP	HCl REACTION	Surface pH	Hydraulic Oil Penet.	Engine Oil Penetration	Surface Strength
1	1	PCC Control	Vigorous	6	Wets and penetrates	Wets and penetrates	Hard
1	2	CAC Fondag	Very Reactive	7	"	"	Very soft
2	1	PCC Control	Very Reactive	6	"	"	Hard
2	2	CAC (Secar 41)	Very Reactive	6	"	"	Very soft
3	1	PCC Control	Vigorous	6	"	"	Dusty & soft
3	2	PCC Test Mix 1 Plus SURTREAT	Very Slight	12	Repelled	Repelled	Hard & strong
4	1	PCC Control	Very Reactive	6	Wets and penetrates	Wets and penetrates	Hard
4	2	PCC Test Mix 2 plus SURTREAT	Reactive	12	Wets and partial pen.	Repelled	Hard
5	1	PCC Control	Very Reactive	6	Wets and penetrates	Wets and penetrates	Hard
5	2	PCC Test Mix 3	Reactive	6	"	"	Hard
6	1	PCC Control	Very Reactive	6	"	"	Hard
6	2	PCC Test Mix 3	Reactive	6	"	"	Soft

Level of HCl Reactivity -
High - Vigorous - Very Reactive - Reactive
Low - Slight - Very Slight

PHOTO #1

PHOTO #2

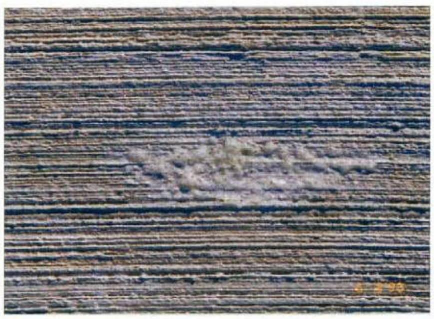


PHOTO #3

PHOTO #4

PHOTO #5

PHOTO #6

PHOTO #7

PROJECT REPORT

SEYMOUR JOHNSON AIR FORCE BASE
GOLDSBORO, NORTH CAROLINA

January 21, 1997

PROJECT REPORT:

Inhibiting Formation of FOD Concrete Fragments
Seymour Johnson Air Force Base Runways

Prepared for:

4th Civil Engineer Squadron
Seymour Johnson Air Force Base
Goldsboro, NC

Date:

January 21, 1997

Contents:

I Project Background

The concrete taxiways and runways at Seymour Johnson Air Force Base were poured in the 1958 to 1960 period. The pavement is about 21 inches thick. Fine longitudinal cracks were first reported in 1964. The cracks are uniformly spaced about 31 inches. Over time, the cracks have enlarged, and additional small cracks have propagated from them. These cracks lead to the formation of concrete fragments which become airborne and have the potential of being sucked into jet engines causing damage (FOD).

The Air Force in cooperation with the Army Corps of Engineers is investigating methods for stabilizing the concrete surface to prevent fragmentation and FOD.

Surtreat Corp. was invited to conduct a demonstration of the **SURTREAT** concrete protection and restoration process on a 1800 sq. ft. section of the taxiway October 14th and 15th of 1996.

The **SURTREAT** process involves the surface application of water soluble chemical formulations which penetrate the surface to a depth of 2 inches, and react with the cement phase to increase strength, decrease porosity, and inhibit rebar corrosion and cement chemical degradation.

II Demonstration Project

Surtreat Corp. applied 45 gallons of **SURTREAT-GPHP** to 1800 sq. ft. of taxiway surface on October 14, 1996. Two applications of 25 gallons and 20 gallons were made followed by the application of water chasers of 20 and 30 gallons. The water chasers were made to force all of the **SURTREAT-GPHP** ingredients into the concrete, and not leave any material on the surface, which might change surface friction properties. The application rate over the 1800-sq. ft. area was 40-sq. ft. per gallon. Concrete strength and porosity were measured before and after applications of **SURTREAT-GPHP**. The after application measurements were made on October 15, 1996.

Concrete strength is determined by measuring the force in kilo Newton's (kN) required to pull a 2 x 1 inch plug from the concrete surface. This force is also expressed in the more conventional psi compression strength scale.

Condition	Pull Out Strength kN	Relative Compression Strength – psi
After Application	42	6,850
Before Application	37	6,000
Change	5	850
Percent Change	13.5	14.0

The concrete pavement has a high compression strength as would be anticipated for military runways. The increase in overall strength is modest in percentage terms, but is a significant indication of how **SURTREAT-GPHP** can increase the surface strength of concrete. It is anticipated that the increase may be even greater in areas along the crack faces which have become weak and are prime sources of fragments.

Water permeability if measured by fixing a 3-inch diameter cell to the concrete surface and measuring the rate of water penetration at 1.0 atmosphere of constant hydrostatic pressure.

Condition	Time Minutes	Volume cc Water	Rate cc/Minute
After Application	10	0.5	0.05
Before Application	1	10.0	10.0
Degree of Change			9.95
Percent Change			99.5%

SURTREAT-GPHP has significantly reduced the micro porosity of the pavement. There is still significant porosity around the cracks, but little opportunity for water to penetrate the cement phase and cause bond weakening between the aggregate.

IV Appendix

Photographs showing the following stages of application and procedure are presented as follows:

Photo 1

Concrete surface before application of **SURTREAT-GPHP** showing major longitudinal cracks and smaller radial cracks.

Photo 2

Application of **SURTREAT-GPHP** to concrete surface.

Photo 3

Concrete surface after application of **SURTREAT-GPHP**. The outline of micro cracks can be seen where **SURTREAT** has penetrated.

Photo 4

Shows the pull out strength and porosity measurement instruments in place ready to measure concrete properties after application.

SURTREAT–GPHP APPLICATION AT SEYMOUR JOHNSON AIR FORCE BASE

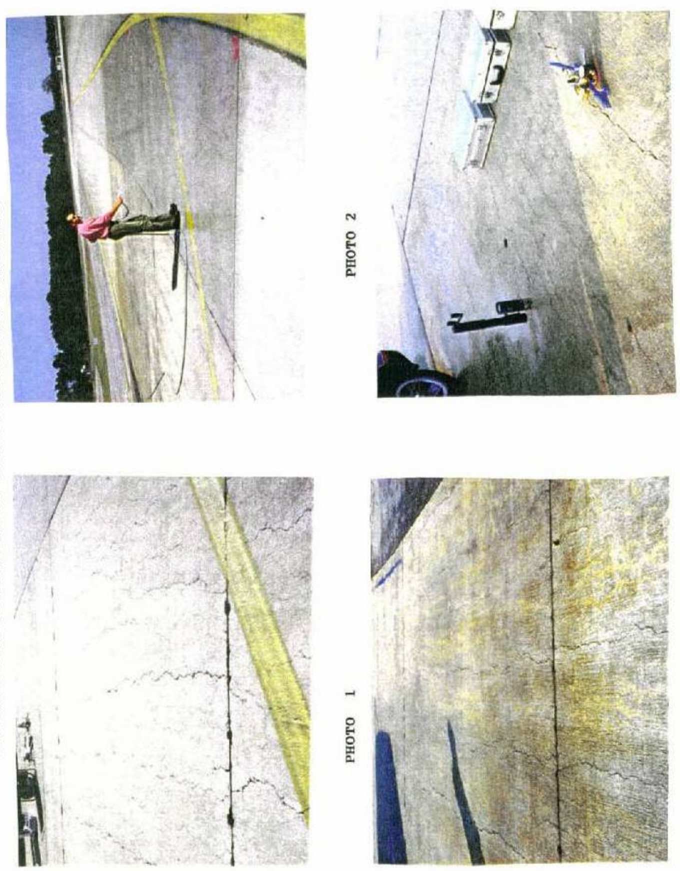


PHOTO 1

PHOTO 2

PHOTO 3

PHOTO 4

CHEMTRON APPLICATION AT SEYMOUR JOHNSON AIR FORCE BASE

PHOTO 5

Appendix B: Detailed Description of Technology Application Procedure

Preliminary condition testing

To establish proper corrosion inhibitor selection a battery of field tests were performed in January 2007. This data was used to anticipate time and material required to properly restore the concrete and install the inhibitor protection system. The following tests were performed at Naha Port and Kuwae tank farm:

- ring girder — corrosion rate and compressive strength (Building 306)
- culvert 2 — water permeability, corrosion rate, pH, compressive strength, and chloride content (Kuwae Tank Farm)
- culvert 3 — visual observation (Kuwae Tank Farm).

These tests were performed to establish concrete and rebar condition but not as a baseline reference for future evaluation.

Building 306 ring girder

Corrosion rate test

Corrosion testing showed average corrosion rate of 10 µM/year, confirming the presence of corrosion in addition to the apparent symptoms like delamination at rebar level, spalling and surface rust stains. The test was carried out using Germann Instruments Galvapulse® method.

Compressive strength test

Compressive strength testing showed an average of approximately 3,000 psi using rebound hammer.

Kuwae culvert 2

Water permeability test

Water permeability showed permeability of 3.6 ml/min at a constant pressure of 1.5 bar (~22 psi.). This value can be described as above average. The test was conducted using GWT® method and Germann Instruments static pressure cell.

Corrosion rate test

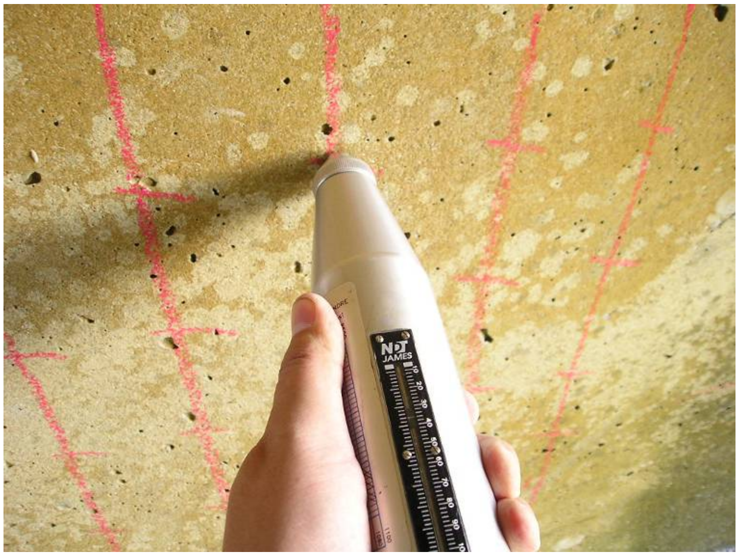
Corrosion rate was measured at three locations on bridge supports. Tests were conducted using the Germann Instruments Galvapulse® method. Test area A showed the average corrosion rate of 34 µM/year; test area B showed the average corrosion rate of 35 µM/year; and test area C showed the average corrosion rate of 38 µM/year Based on these findings condition of the embedded steel bar can be described as corrosive.

pH test

Concrete pH was measured using Rainbow pH Indicator® and showed loss of concrete pH at the surface. Tests were performed in two locations, and returned similar results.

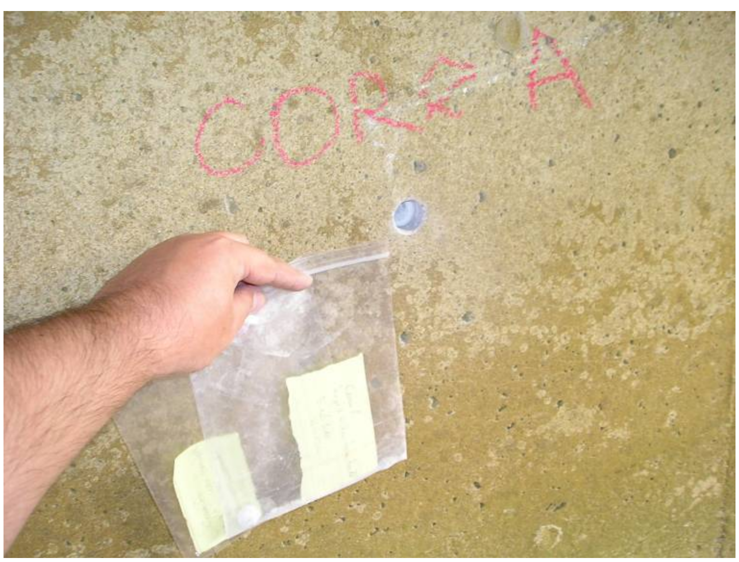
Compressive strength test

Rebound hammer was used to estimate compressive strength at approximately 4,000 psi. Tests were conducted in two locations and returned similar results.



Chloride content

Samples were collected at the two pH test site locations and evaluated using the RCT® (Rapid Chloride Test) method. The test found negligible chloride presence in the test samples.



Kuwae culvert 3

No tests were performed on culvert 3. Based on visual inspection, culvert 3 was assumed to be similar to culvert 2 in all respects that would affect corrosion prevention and control treatments.

Application of CPC technologies

Naha Military Port, Building 306, section A, ring girder sides 1 and 2

Surface preparation

Scaffolding was brought in and constructed to facilitate work in Building 306 Naha Military Port.

Existing coatings were checked for lead before they were removed. Red coloring on the detection swab would have indicated the presence of lead. The indicator turned yellow, however, meaning that no lead was present.

Coatings were removed using a grinder with a dust-collection system.

Failed existing repairs and new delaminated areas were demolished.

Concrete repair

Exposed rebar in repair areas was cleaned by using wire wheel.

Rust Converter direct contact corrosion inhibitor was applied to the exposed rebar in demolished repair areas.

Organic vapor phase corrosion inhibitor and inorganic migratory corrosion inhibitor were applied to the demolished repair areas in sequence followed by intermittent water spray and additional washing following the application. A hand pump was used to facilitate application.

Electrical connections to the rebar were made to facilitate future testing as well as to assure proper installation and performance of the LGC on Side 2 of the Ring Girder.

Concrete was mixed from local masonry with polymer added for improved strength and durability.

Repair areas were primed prior to concrete placement.

Concrete repairs were placed and finished in accordance with generally accepted construction practices in all locations on the ring girder side 1 (Surtreat system) and 2 (LGC)

An example of concrete repairs to ring girder side 1 is shown below.

An example of concrete repairs to ring girder side 2 is shown below..

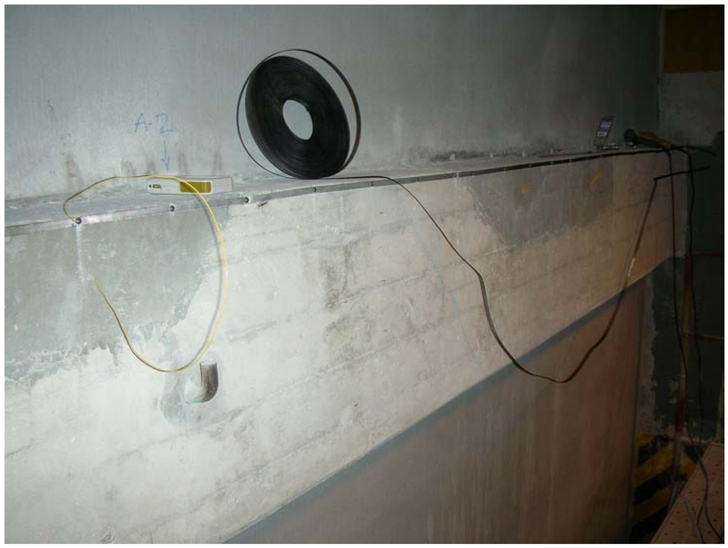
Corrosion inhibitor system application to ring girder side 1

Organic vapor phase corrosion inhibitor and inorganic migratory corrosion inhibitor were applied in sequence to all newly placed and remaining concrete surfaces on Side 1 of the Ring Girder.

Reactive silicone surface protection agent was applied to all newly placed and remaining concrete surfaces on Side 1 of the Ring Girder.

LGC application to ring girder side 2

Installation of the titanium mesh component of the LGC.



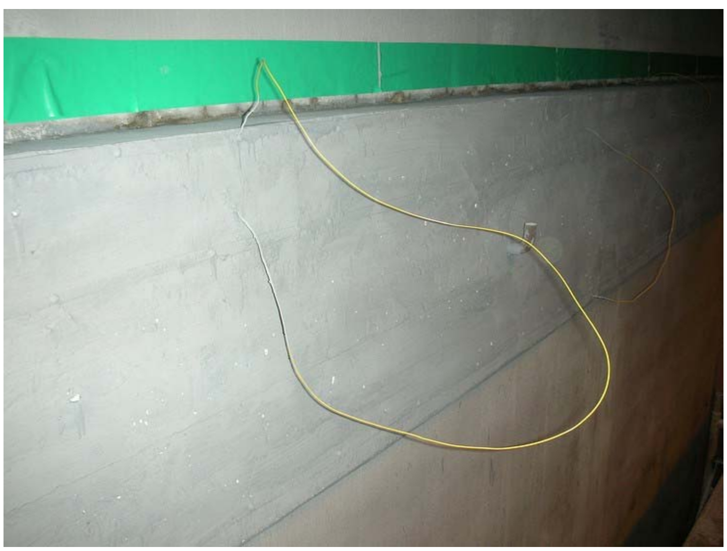
Appearance of the Ring Girder Side 2 prior to application of the LGC.

Equipment and components were assembled and the surface prepared for application of the LGC to side 2 of the ring girder.

Following spray application, touch-up performed by brush.

Appearance of the Ring Girder Side 2 immediately following application of the LGC.

Finished appearance of the Ring Girder Side 2 following application of the LGC.



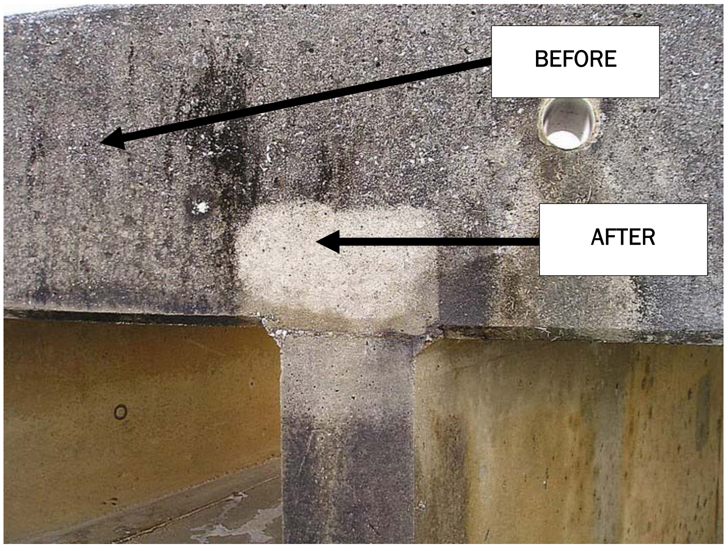
Kuwae Tank Farm culverts 2 and 3

Surface preparation

Equipment and water delivery assembled at Kuwae Tank Farm Culvert 2.

All exposed concrete surfaces were pressure washed on Culvert 2. Vertical support structure was pressure washed on Culvert 3.

Contrast between the clean and contaminated concrete surface (Culvert 2)



Deterioration and spalling pattern common to Culvert 2.

Concrete repair

All repair areas were "squared" and patched using locally manufactured overhead mortar.

Corrosion inhibitor application

Organic vapor phase corrosion inhibitor was applied using an electric pump with lance followed by intermittent water spray to prevent drying and facilitate penetration (Culvert 2).

Several days passed between applications of organic vapor phase corrosion inhibitor and inorganic migratory corrosion inhibitor.

Inorganic migratory corrosion inhibitor was applied using an electric pump with lance followed by intermittent water spray to prevent drying and facilitate penetration (Culvert 2).

Culvert 2 appearance immediately following corrosion inhibitor system application.

Inorganic migratory corrosion inhibitor was applied using a hand pump with sprayer followed by intermittent water spray to prevent drying and facilitate penetration (Culvert 3).

Reactive silicone surface protection agent was applied to all exposed concrete surfaces of Culvert 2 using a hand pump sprayer.

Reactive silicone surface protection agent was applied to all vertical support components of Culvert 3 using a hand pump sprayer.

Follow-up testing

Naha Military Port, Building 306, section A, ring girder sides 1 and 2

Initial testing (before repairs and corrosion mitigation) was performed in January 2007. Follow-up testing was performed in July 2007. The follow-up testing followed the exact pattern of initial testing with all the points

laid out precisely as they were for the “before” corrosion testing. The exact same locations were used for the “before and after” water permeability testing.

Corrosion testing using Galvapulse® method. Sections of both sides of the Ring Girder were tested before and after corrosion mitigating components were applied/installed (Naha Military port Building 306 Ring Girder Sides 1 and 2.)

Water Permeability testing using the GWT method. Both sides of the girder were tested “before and after”.

Galvapulse® Psion unit.

The points on the grid established during initial testing match exactly the points of the follow-up testing. The photograph also shows where the measurements were influenced by additional wire inside the repair installed to hold the patch in place during curing. During initial testing some of the repair areas could not be tested due to spalling.

A digital multi-meter and various shunt resistances were used to measure the current flow from the sacrificial coating to the reinforcing steel On Side 2 of the Building 306 Ring girder (LGC).

Coating was removed in selected locations to allow the follow-up testing for Ring Girder Side 2 - LGC.

Potential measurements of the sacrificial coating and the reinforcing steel were also made.

Culvert 2

Initial testing (before repairs and corrosion mitigation) was performed in January 2007. Follow-up testing was performed in July 2007.

The follow-up testing followed the exact pattern of initial testing with all the points laid out precisely as they were for the “before” corrosion testing. The exact same locations were used for the “before and after” water permeability testing.

Water Permeability testing using the GWT method (Kuwae TF Culvert 2).

Corrosion testing using Galvapulse® method (Kuwae TF Culvert 2)

It was also noted during the follow-up corrosion testing on Culvert 2 that the measurements on the repair material used for patching were higher. Further investigation showed that the mortar contained additives that interfere with the reading.

Appendix C: Elzly Final Report

Survey of Military Structures in Okinawa, Japan
Before and After Rehabilitation using
Surtreat Inhibitor System or
Sacrificial (Galvanic) Coating

Prepared for
Surtreat Holding, LLC

Prepared by
Elzly Technology Corporation

August, 2007

Elzly
Technology
Corporation

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List of Sketches (Appendix A)

Executive Summary

This report presents the results of an evaluation of two technologies for protecting concrete reinforcing steel from corrosion. The technologies evaluated are a Surtreat Holding, LLC reinforced concrete chemical corrosion inhibitor system and a NASA-developed sacrificial cathodic corrosion protection coating. The evaluation was conducted on reinforced concrete structures in need of repair at US military facilities on the island of Okinawa, Japan. The project is sponsored by the US Army Corps of Engineers (COE) laboratory (Champaign, IL) and is funded by the DOD Corrosion Policy and Oversight Office. Data presented in this report was collected by personnel from Surtreat Holding, LLC and Elzly Technology Corporation.

The concrete structures were selected by the COE along with Surtreat during an initial visit to Okinawa during November of 2006. They are two culverts located at the fuel tank farm for Kadena AFB, and two ring girders in the north east end (section A) of Warehouse 306 at the Naha military port. The two culverts are exhibiting early symptoms of rebar corrosion as evidenced by a few areas of concrete spalling. The two ring girders in the Naha Port Warehouse 306 exhibited symptoms of significant rebar corrosion in the form of concrete spalling and rusting rebar. It appears that the ring girders are experiencing corrosion at a higher rate than the other warehouse structural members due to water running down the inside of the concrete block wall and into the girder. The water may be penetrating the block wall from outside or there may be leaks in the roof.

In January, 2007 testing was performed to characterize the condition of the structures prior to rehabilitation. Elzly personnel observed and documented the testing performed by Surtreat personnel. Drawings were compiled to document the existing condition of the concrete and test locations. The scope of the testing was previously agreed upon between Surtreat and the Government. The survey was adequate to form a baseline against which to compare the future condition of the structures. The rehabilitation and repairs were performed in early February, 2007 after the characterization testing. Elzly did not observe the execution of repairs.

In July, 2007 follow-up testing was performed by Elzly and Surtreat personnel to quantify the effectiveness of the repairs at mitigating reinforcing steel corrosion. The results showed that the inhibitor system substantially reduced corrosion of the reinforcing steel. Corrosion has been reduced to negligible levels (below 23.2 μm/yr [0.95 MPY]) on the majority of the structures. It is estimated that the inhibitor treatment will extend the need for corrosion repair by more than 10 years. The results are less conclusive for the sacrificial coating. Data suggests a small decrease in corrosion rate. However, complicating factors in the measurement of a cathodically protected system make it possible that the actual steel corrosion rate is lower than measured.

Continued monitoring of the inhibitor system performance is recommended to determine the service life and future maintenance requirements for the inhibitor system. However, continued monitoring should not preclude further implementation of the inhibitor system where mitigation of reinforcing steel corrosion is desired. Based on the testing conducted, it is clear that the inhibitor has a beneficial effect. The sacrificial coating requires further study to understand if it is a feasible technology for protection of reinforcing steel from corrosion.

Conclusions

1. The data quantitatively shows that the Surtreat inhibitor application has significantly reduced the corrosion of the reinforcing steel. It can be projected that the service life has been extended by more than 10 years based on the short-term data collected.

2. The galvanic coating appears to be providing some protection to the reinforcing steel; however, it is difficult to quantify the extent to which it will extend the service life of the structure. More can be learned about this sacrificial coating through periodic surveys of its performance in the coming years.

3. All of the treated structures were experiencing significant rebar corrosion prior to rehabilitation. The corrosion seems to be due to carbonation of the concrete rather than the more common chloride-induced corrosion. At the time of testing, the rebar in the northern half of the beam in Building 306 (Beam 2) were corroding at the highest rate, followed by the southern half of the beam (Beam 1) and then Culvert #2. Both beams in building 306 had several locations where concrete repair patches were evident. Culvert #3 at the Kuwae Tank Farm had some type of mortar repair. Culvert #2 did not appear to have any previous repairs, though some spalling was evident. Measured corrosion rates suggest that concrete repair will be necessary on Culvert #2 in 2-10 years.

4. The ring girders in building 306 have active reinforcing steel corrosion and require rehabilitation. The migratory inhibitor was the best system tested. It will slow the reinforcing steel corrosion and subsequent concrete spalling. Other buildings at Naha Port should also be inspected for similar corrosion.

Recommendations

1. Continue to use the migratory inhibitor technology to protect reinforcing steel from corrosion. Monitoring of additional projects would enhance the existing body of data on the service life extension (and economic value) which can be offered by the product. Specifically, it would be useful to monitor a structure where chlorides (rather than carbonation) were the dominate cause of reinforcing steel corrosion.

2. Continue to survey the structures treated with Surtreat to determine the rebar corrosion rate. In addition to confirming the protection afforded by the system, the data will be useful in quantifying if or when the inhibitor treatment should be repeated. The GalvaPulse instrument seems to be ideal for determining the rebar corrosion rate. For experimental purposes, data should be collected at least annually on the test structures.

3. Develop appropriate documents to institutionalize the Surtreat system as a maintenance procedure for reinforced concrete. This would include the development of guide specifications (e.g., UFGS), manuals, and standards for use by the Army Corps of Engineers.

4. Continue to investigate the performance of the sacrificial coating. The sacrificial coating interferes with the GalvaPulse measurement, so alternative evaluation methodologies should be developed. It is apparent that the sacrificial current output (protective current) increases as the concrete becomes wet (i.e., more corrosive to rebar). To fully understand the performance of the sacrificial coating, it should be evaluated under a range of wetted conditions.

5. The locally procured patch material seems to induce a higher corrosion rate than would otherwise be expected. The reasons for this should be investigated and communicated to local maintenance personnel. If the cause is significant enough, the Army Corps of Engineers should consider developing guidance for the procurement of concrete patch materials.

6. The ring girders in Building 306 seem to suffer from corrosion related to water ingress either through the block wall or from the roof. A root cause analysis should be performed to identify the source of water. If the water can be reduced or eliminated, reinforcing steel corrosion would also be reduced. The results of the root cause analysis should be applied to the other buildings of similar construction at Naha Port and other facilities in Okinawa.

Procedures

In November, 2006 Surtreat and COE personnel made a visit to Okinawa to select structures for the demonstration. During that visit, visual observations and physical measurements were made of the structures which were ultimately selected for testing. Elzly personnel were not present for that testing but some of that data is referenced in this report.

The structures selected for testing include two culverts located at the Kuwae Tank Farm and two ring girders in the north east end (section A) of Warehouse 306 at the Naha military port. The two culverts (identified as Kuwae Tank Farm Culvert #2 and #3) carry access roads over a storm water spillway. They are exhibiting early symptoms of rebar corrosion as evidenced by a few areas of concrete spalling. The two ring girders in Naha Port Warehouse 306 exhibited significant symptoms of rebar corrosion in the form of concrete spalling and rusting rebar. It appears that the ring girders are experiencing corrosion at a higher rate than the other warehouse structural members due to water running down the inside of the concrete block wall and into the girder. The water may be penetrating the block wall from outside or there may be roof leaks.

On January 18 through 22, 2007, Elzly personnel observed preliminary testing and condition assessment of three structures which were subsequently repaired and preserved with a proprietary inhibitor manufactured by Surtreat. The three structures are located on U.S. military facilities in Okinawa, Japan. The structures included two concrete culverts at Kuwae Tank Farm #2 and a concrete beam along the west wall of Building 306 at the Naha Port. Elzly observed and documented testing performed by Surtreat personnel and compiled drawings and text which describe the existing condition of the concrete and locations of the tests.

On July 20 through 25, 2007 Surtreat personnel performed measurements similar to those performed prior to treatment. Elzly personnel witnessed the work on July 24 and 25. Elzly performed additional measurements to quantify the effectiveness of the experimental galvanic coating.

The scope of the testing to be performed was previously agreed upon between Surtreat and the Government. The key testing conducted before and after the inhibitor application included:

Rebar Corrosion Rate. Corrosion rate was measured using GalvaPulse, a rapid, non-destructive polarization technique for the evaluation of reinforcement corrosion rate. The galvanostatic pulse technique was introduced for field application in 1988.[1] The system applies a galvanostatic pulse to the reinforcing steel and measures the potential response. The rebar corrosion rate is estimated using the Stern-Geary equation. The technique has been shown to reliably assess reinforcing steel corrosion.[2,3]

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[1] Elsener B.: "Elektrochemische Metoden zur Bauwerksüberwachung", Zerstörungsfreie Prüfung an Sthalbetonbauwerken, SIA Dokumentation D020, Schweizer Ingenieur- und Architektverein, Zürich, 1988,27.
[2] Elsener, B., Wojtas, H. & Bohni, H.: "Galvanostatic Pulse Measurements - Rapid on Site Corrosion Monitoring", Corrosion and Corrosion Protection of Steel in Concrete, Vol. 1, pp 236-246, Proceedings of International Conference held at the University of Sheffield, 24-28 July, 1994
[3] Klinghoffer O., Frølund T., Rislund E., Elsener B., Y. Schiegg Y., Bohni H.,: "Assessment of reinforcement corrosion by means of galvanostatic pulse technique" International conference: Repair of Concrete Structures. Svolvær, Norway, May 1997

Water Permeability. The water permeability of the concrete was measured in accordance with ISO 7031, *Concrete Hardened – Determination of Permeability* using a Germann Instruments "GWT-4000." A sealed pressure chamber is attached to the concrete surface, the chamber is filled with water and a water pressure (typically 1 bar) is applied to the surface. The pressure is kept constant using a micrometer gauge with attached pin that displaces the water leaving the chamber. The difference in the gauge position over a given time is converted to a flux which represents the water penetrability at the test water pressure.

During each of the visits, water permeability was also measured with a Rilem Tube. The Rilem Tube is essentially a graduated cylinder attached to the concrete using putty. When attached, the cylinder is filled with water such that approximately 0.14 psi of water pressure is on the surface. Over time, the amount of water which penetrates into the concrete is measured in mL.

Concrete Chemistry and Strength. Concrete chemistry and strength were characterized on Culvert #2 during the November, 2006 visit. The chloride content was measured on powder samples removed from the structure with a hammer drill. Standard wet chemistry techniques were used to determine the chloride content. Chlorides in the concrete can locally disturb the passive film on reinforcing steel, allowing corrosion to begin.

The pH of the concrete was determined at various depths to characterize the extent of carbonation in the concrete. Carbonation occurs when calcium converts to calcium carbonate in the presence of moisture. This reaction lowers the pH of the concrete below that in which steel is normally passive. Carbonated concrete is typically softer and will delaminate easier than chloride contaminated concrete.

Compressive strength of the concrete was determined using an impact hammer. The compressive strength of concrete is an indicator of the concrete quality.

Sacrificial Coating Evaluation. Various electrochemical measurements were made to evaluate the performance of the sacrificial coating. A digital multimeter and various shunt resistances were used to measure the current flow from the sacrificial coating to the reinforcing steel. A circuit box was designed to facilitate measurements by isolating the current collection points from the rebar with a simple switching circuit. Potential measurements of the sacrificial coating and the reinforcing steel were also made with the sacrificial coating connected and disconnected from the circuit. The shift in electrochemical potential of reinforcing steel is an indication of effective cathodic protection.

Observations – Kuwae Tank Farm #2

A spillway runs nominally east to west within Kuwae Tank Farm #2. The spillway carries rainwater runoff from Kadena Air Force Base to the East China Sea. Two culverts carry service roads across the spillway within the tank farm perimeter. A third culvert at the fence line carries route 58 over the spillway. Sketch 1 in Appendix A shows the overall layout of the spillway. The present work includes rehabilitation of the two culverts within the tank farm perimeter (Culverts #2 and #3).

It was reported that the culverts were constructed in the 1950's, though no records were provided. Both of the culverts to be repaired are of similar construction. They include three piers and two abutments which support a small access road. The survey focused on the piers and abutments. Each of the pier/abutment walls appears to have been fabricated using wooden forms in three primary sections. Plugs were evident in a clear pattern consisting of three rows (8, 29, and 50 inches from the culvert floor) and spaced between 20-30 inches apart. It is assumed that these were locations where steel bars used to hold the forms in place were cut and patched.

Culvert #2

Culvert #2 is located in the middle of the spillway section within the tank farm. Figure 1 shows a general overview of the culvert, looking downstream toward the East China Sea. Light rains with periodic heavy rain throughout the first day of inspections resulted in brisk water flow through the culvert, as much as a foot deep. Sketches 2 and 3 (Appendix A) depict the existing condition of the pier walls on Culvert #2 as well as the location of all tests conducted. Generally, the form dimensions were easily visible and could be used as reference points.

Figure 1. Overview of Culvert #2, looking downstream toward the East China Sea.

Figure 2. Exposed rebar on Culvert #2.

Rebar was exposed where concrete had been spalled in four areas. The exposed rebar was used for measurements with the GalvaPulse. Figure 2 shows representative exposed rebar. Corrosion is readily apparent on the exposed rebar (nominally 3/8-inch diameter), though it was difficult to quantify the metal loss. The spalled areas were repaired by Surtreat during the rehabilitation and re-opened in July to facilitate future measurements.

Overall, the concrete appeared to be in good shape. Vertical cracks were observed in the center of each pier and abutment. The approximate locations of these cracks are noted in the sketches. No evidence of previous repairs was observed (except for one bug hole which was patched with some type of mortar). The surface was smooth except for bug holes and form marks. The surface was stained brown along most of the pier surfaces. A typical surface is shown in figure 3. The upstream leading edge of the pier was deteriorated (likely by abrasion of impact of debris), with chunks up to three inches removed. Figure 4 shows typical damage on the upstream edge of the culvert piers.

Figure 3. Typical pier wall surface containing a crack and plugged area.

Figure 4. Typical damage on the upstream edges of the culvert #2 piers.

The Surtreat inhibitor system was applied to the floor, piers, and underside of the deck of culvert #2 in early February, 2007. On July 24, 2007, approximately 6 months after application, the culvert was inspected. The surfaces all appeared to be in good condition. The surfaces were noticeably cleaner from the rehabilitation project (i.e., the brown stain was no longer evident on the piers). Figure 5 shows the condition of the downstream end of the south face of "pier A" before and 6 months after the inhibitor treatment.

Several small patches of cementitious repair material were noted on the structure at the July inspection. These patches were applied by others between completion of the Surtreat work and our July inspection. Details regarding the reason for repair and the procedures used are not known. Figure 6 shows typical repairs. Note that the repair material has a rough appearance and is beginning to exhibit cracking.

Figure 5. Typical appearance of culvert before (left) and 6 months after (right) inhibitor application.

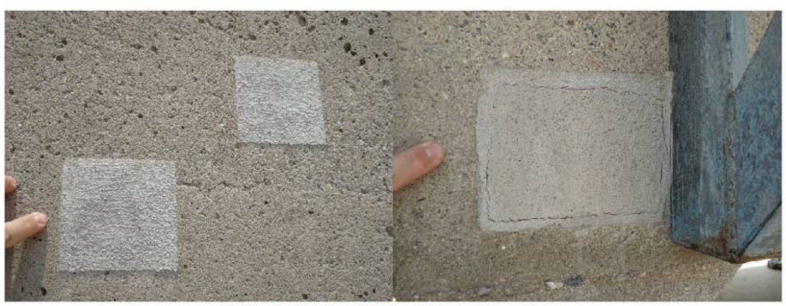


Figure 6. Typical repairs performed by others.

November, 2006 Concrete Tests – Culvert #2

During the November, 2006 visit the concrete was characterized by Surtreat. Rebar was exposed due to spalling in an area where the concrete cover was only 1.5cm. Galvapulse tests showed corrosion rates averaging 36 µm/yr.

Concrete pH measurements showed that the carbonation front had reached a depth of 1cm. Total chloride content was determined to be 50 ppm (a trace amount) at 0 to 4.5cm of concrete depth. Water permeability was measured at 1.5 amt. of pressure. The micrometer was moved 10 mm over 165 seconds to maintain 1.5 bar of hydrostatic pressure. This corresponds to a flux of 1.58 x 10^{-3} mm/s at 1.5 bar. Compressive strength was measured using the impact hammer method and averaged 4,500 psi.

Water Permeability Tests – Culvert #2

A water permeability test was conducted before application of Surtreat and approximately 6 months afterwards in three locations in accordance with ISO 7031 using GWT apparatus. Figure 7 shows the water permeability before and after Surtreat application. There was nearly an order of magnitude lower water permeability 6 months after application of the Surtreat system.

- Test Location "A" was situated on the northernmost pier, south face. It was approximately 303 cm from the downstream end of the pier and 62 cm from the culvert floor. Initial testing was performed on January 19, 2007. The micrometer was moved 10 mm over 185 seconds to maintain 1 bar of hydrostatic pressure. This corresponds to a flux of 1.41 x 10^{-3} mm/s at 1 bar. Post–treatment testing was performed on July 24, 2007. The micrometer was moved 8.5 mm over 600 seconds to maintain 1 bar of hydrostatic pressure. This corresponds to a flux of 3.69 x 10^{-4} mm/s at 1 bar.

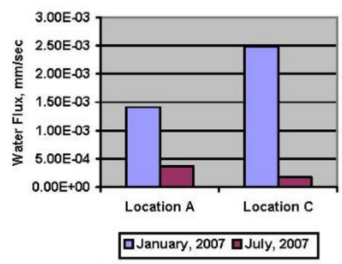


Figure 7. Water permeability change before and after inhibitor application.

- Test location "B" was situated on the southernmost pier, south face. It was approximately 120 cm from the upstream end of the pier and 63 cm from the culvert floor. Testing was performed on January 19, 2007. The test was inconclusive due to a leaking seal. No post-treatment testing was performed at this location.
- Test Location "C" was situated on the middle pier, south face. It was approximately 122 inches from the upstream end of the pier and 22 inches from the culvert floor. Testing was performed on January 22, 2007. The micrometer was moved 10 mm over 105 seconds to maintain 1 bar of hydrostatic pressure. This corresponds to a flux of 2.48 x 10^{-3} mm/s at 1 bar. Post–treatment testing was performed on July 24, 2007. The micrometer was moved 4.0 mm over 600 seconds to maintain 1 bar of hydrostatic pressure. This corresponds to a flux of 1.74 x 10^{-4} mm/s at 1 bar.

GalvaPulse Tests – Culvert #2

On January 22, 2007, GalvaPulse measurements were made in three locations on the structure. These measurements define the baseline condition. In July, 2007 three replicate sets of GalvaPulse measurements were made. In total, 54 measurements were made before and 162 measurements were made after treatment. Table 1 identifies each data set along with the average and median values for each set. Corrosion rates are reported in both micrometers per year (µm/yr) and mils (0.001-inch) per year (MPY). Substantial corrosion rate reductions were observed.

Table 1 - Culvert 2 Corrosion Rate Measurements

	Before Treatment (January, 2007)	After Treatment (July, 2007)	Reduction
Median (50% probability)	29.8 µm/yr (1.17 MPY)	7.8 µm/yr (0.31 MPY)	74%
Average	37.4 µm/yr (1.47 MPY)	13.1 µm/yr (0.52 MPY)	65%

The reports from the Galvapulse instrument provide all of the individual measurements. As might be expected with a phenomena bounded on end (i.e., the corrosion rate cannot be less than 0), the data distributes itself such that the median and average do not coincide. To obtain better insight to the data, the corrosion rate data taken in each timeframe was plotted on a cumulative probability graph. Figure 8 shows the distribution of measured values. This representation of the data shows a clear reduction at all levels of corrosion. The reductions range from a factor of two to ten.

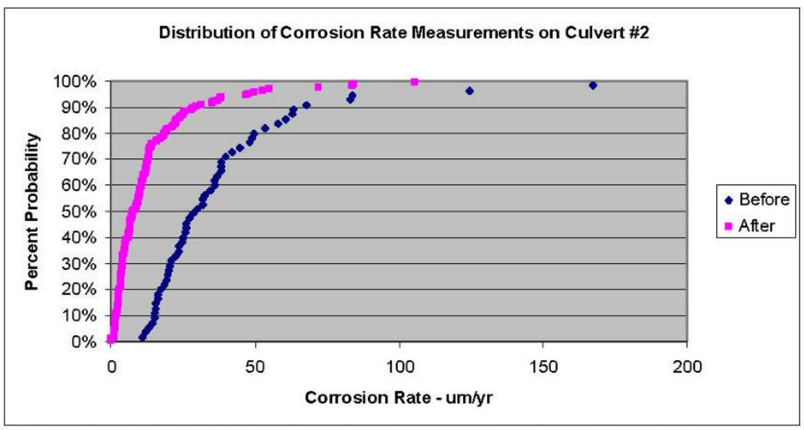


Figure 8. Probability distribution of corrosion rate measurements before and 6 months after inhibitor application.

An alternative way to look at the same data is to classify the corrosion rate measurements as described by Frolund, et.al.[4] The quantity of corrosion rates in each of five broad categories of severity is expressed as a percentage of all measurements. Figure 9 shows this data before and after the inhibitor application. The data suggests that more than 80% of the structure has negligible corrosion activity after inhibitor application.

A similar classification technique developed by Clear attempts to correlate service life to corrosion rates.[5] Figure 10 shows the data from culvert #2 in this classification scheme. Based on this analysis, the structure initially could have expected corrosion damage on over 50% of the structure in 2 to 10 years without treatment. Subsequent to treatment, no corrosion damage is expected on 40% of the structure, and the majority of the remaining structure has corrosion damage possible in 10 to 15 years. Based on this analysis, it seems reasonable to conclude that the inhibitor treatment application has extended the service life of the structure by at least 10 years.

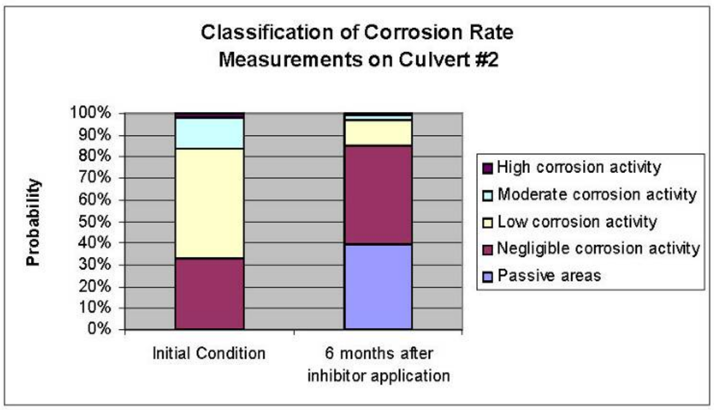


Figure 9. Corrosion activity before and after inhibitor application.

[4] Frølund, T., Jensen, F.M. & Bässler, R., "Determination of Reinforcement Corrosion Rate by Means of the Galvanostatic Pulse Technique," *First International Conference of Bridge Maintenance*, IABMAS 2002, Barcelona, Spain.

[5] K. Clear, "Measuring Rate of Corrosion of Steel in Field Concrete Structures," paper no. 88-0324, 68th Annual Transportation Research Board Meeting, 1989.

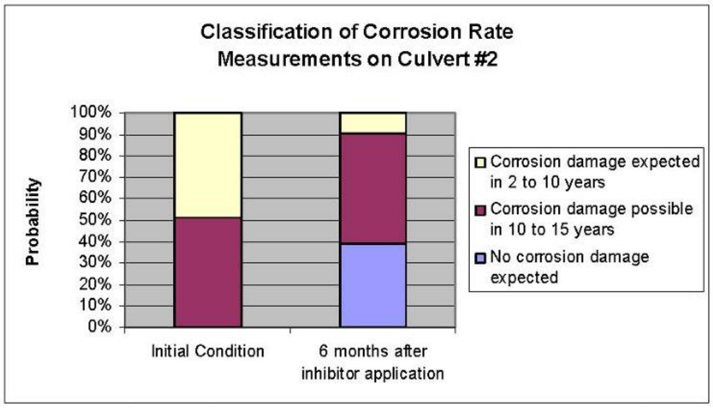


Figure 10. Corrosion damage projections for culvert #2 based on corrosion rate data.

Culvert #3

Culvert #3 is located at the extreme western end of the spillway (i.e., nearest to the East China Sea). Figure 11 shows a general overview of the culvert looking toward the East China Sea. Sketches 4 and 5 (Appendix A) depict the existing condition of the pier walls on Culvert #3.

Culvert #3 had a cementitious repair material applied to the upstream ends and other locations. It is not known when the repairs were performed or what material was used. Figure 12 shows typical repaired areas (lighter colored material). The upstream patches had straight edges while the downstream patches were less neatly finished. Some vertical cracking was observed in the approximate center of the pier walls. The approximate locations of the repair material and vertical cracks are noted in the sketches. No delamination of concrete from the reinforcing steel was visually evident. Some of the plugs were also patched. Several plugs were observed with delamination which revealed a steel bar recessed approximately ¼ to ½-inch. Figure 13 shows the exposed steel within one of these plugs.

The Surtreat inhibitor system was applied to the piers of the structure in early February, 2007. During our July, 2007 inspection the structure appeared to be in good condition. However, it was observed that vertical cracks on several of the piers had a cementitous repair material applied over them. Details of the repair work are not known. Figure 14 shows the south abutment face in January and July 2007. Note the patch repair that was completed as well as the overall improvement in appearance of the concrete associated with the cleaning and application of the inhibitor.

No corrosion or water transmission data was taken on this culvert either before or after application of the inhibitor.


Figure 11. Overview of Culvert #3, looking downstream toward the East China Sea.


Figure 12. Typical previously repaired areas (lighter mortar) on Culvert #3.

Figure 13. Typical steel within a delaminated "plug."

Figure 14. Typical appearance of culvert before (left) and 6 months after (right) inhibitor application.

Naha Port – Building 306

Tests were conducted on a ring girder along the west end of Building 306 at the Naha military port. The beam is approximately 25 inches high by 7 inches thick. There are two sections of beam to be repaired, each approximately 38 feet long. The section of the ring girder designated "Beam 1" begins immediately adjacent to the door and continues to an intersection with a vertical column. The section of the ring girder designated "Beam 2" is the section which begins on the other side of the vertical column and ends at the column in the corner of the building. Sketches 6 and 7 (Appendix A) show significant features of Beams 1 and 2, respectively. Figures 15 and 16 show overviews of Beam 1 and Beam 2, respectively.

On January 18, Surtreat personnel exposed rebar under spalled concrete in two locations on each beam. The exposed rebar was heavily corroded. While the corrosion could not be measured precisely, there was evidence of several millimeters of corrosion. Figure 17 shows a typical section of exposed rebar. The rebar was approximately 1¼-inch diameter running along the beam. The rebar spacing was approximately seven inches with the top bar approximately three inches from the top of the beam. Vertical rebar "cages" were smaller and placed approximately every 13 inches. Rusted attachments were scattered along the surface of the beams (cut off screws, staples, anchors, etc). Beam 2 had some type of paint applied in the past. It was fairly thin (several mils), gray paint which was peeling in most areas.

Figure 15. Overview of "Beam 1" at Naha Port Building 306.

Figure 16. Overview of “Beam 2” at Naha Port Building 306.

Figure 17. Representative exposed rebar at a repair location.

Evidence from what is assumed to be a previous inspection suggested five Rilem tube water transmission measurements were made on each side, and holes were drilled in each side (likely for chloride measurements and to connect to rebar for a potential survey). These areas were photographed and their locations noted on the sketches.

Beam 1 – Inhibitor Treatment

The portion of the ring girder designated "Beam 1" was treated with the Surtreat inhibitor system and had delaminated sections repaired in early February, 2007. Figure 18 shows the beam during our July visit. Several patches are evident along the top of the beam, including one large patched area to the right of center and smaller ones at either end of the beam. The edges of the repair material appear to be well bonded. Aside from the patches, the remainder of the beam is cleaned to a uniform appearance. Compare Figure 18 (after) to Figure 15 (before).

Figure 18. Overview of Beam 1 in July, 2007.
Note patch repairs (darker appearance). Compare to Figure 15.

Water Permeability Tests – Beam 1 (Inhibitor Treatment)

Several water transmission tests were performed before the January treatment and approximately 6 months after treatment. Overall, the tests show substantially reduced water permeability.

- Water permeability was measured using a Rilem Tube at various sites marked on the beams. Following results were observed before testing:
    - Location AA-1: 1.2 mL after 20 minutes
    - Location AA-2: 0.35 mL after 20 minutes

  Subsequent to testing, a Rilem Tube showed no water transmission after more than 24 hours.
- A water penetrability test was conducted on Beam 1 using GWT apparatus in accordance with ISO 7031. The test was performed approximately 44 inches from the left end of the beam, 12 inches down from the top. This is in the vicinity of test location AA-1. On January 20, 2007 (before treatment), the micrometer was moved 10 mm over 74 seconds to maintain 1.5 bar of hydrostatic pressure. This corresponds to a flux of 3.51×10^3 mm/s at 1.5 bar. On July 25, 2007 the micrometer was moved 9 mm over 600 seconds to maintain 1.5 bar of

hydrostatic pressure. This corresponds to a flux of 3.91 x 10^{-4} mm/s at 1.5 bar, approximately an order of magnitude lower than before the inhibitor application.

GalvaPulse Measurements – Beam 1 (Inhibitor Treatment)

On January 18, Surtreat personnel wetted the beam and covered it with plastic. Moisture was evident under the plastic in some areas when we arrived at approximately 0900 on January 20. On Beam 1, a grid was laid out with points on 12-inch centers from the right end of the beam. The leftmost points were 25 feet from the right support column. Rows were 3½, 11, and 17½ inches from the top of the beam. Contact was made on the exposed rebar located approximately 240 inches from the left end. Valid corrosion rate measurements were obtained at 73 locations before treatment. In July (approximately 6 months after the inhibitor application), three sets of data were taken on the same grid providing 225 valid corrosion measurements. Significant reductions in both average and median corrosion rate were observed as shown in Table 2.

Table 2 - Beam 1 Corrosion Rate Measurements

	Before Treatment (January, 2007)	After Treatment (July, 2007)	Reduction
Median (50% probability)	41.4 μm/yr (1.63 MPY)	5.7 μm/yr (0.22 MPY)	86%
Average	61.3 μm/yr (2.41 MPY)	24.3 μm/yr (0.96 MPY)	60%

The cumulative probability plot in Figure 19 shows all of the corrosion rate measurements made before and after the inhibitor treatment. Note that a few of the measurements after treatment are actually higher than before treatment. Closer examination showed that these corrosion rates were impacted by the concrete patch repair. In 6 out of 10 cases, measurements over the patch areas exhibited a corrosion rate significantly higher than the average for Beam 1. If these data are eliminated from the average,[6] the inhibitor reduced the average corrosion rate to 11.3 μm/yr (0.44 mils per year), an 82% reduction of corrosion rate.

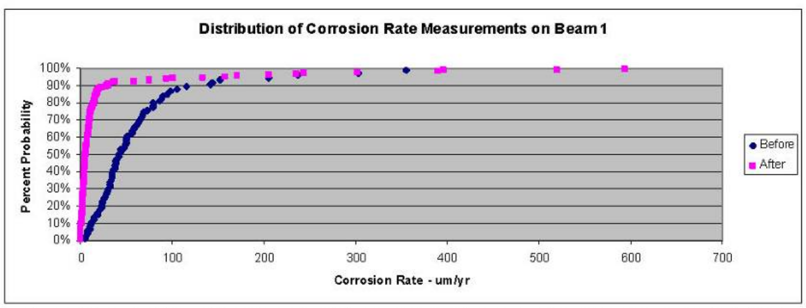


Figure 19. Probability distribution of corrosion rate measurements before and 6 months after inhibitor application.

[6] Removing these data points only slightly reduce the median value.

An alternative way to look at the same data is to classify the corrosion rate measurements as described by Frolund, et.al.[7] The quantity of corrosion rates in each of five broad categories of severity is expressed as a percentage of all measurements. Figure 20 shows this data before and after the inhibitor application. The data suggests that 90% of the structure has negligible corrosion activity after inhibitor application. Also note that the 7.5% of measurements in the moderate and high category correspond to the locations where the local patch material was used.

A similar classification technique developed by Clear attempts to correlate service life to corrosion rates.[8] Figure 21 shows the data from Beam 1 in this classification scheme. Based on this analysis, the structure initially could have expected corrosion damage on nearly 70% of the structure in 2 to 10 years without treatment. Subsequent to treatment, no corrosion damage is expected in half of the structure, and the majority of the remaining structure has corrosion damage possible in 10 to 15 years. By this analysis, it seems reasonable to conclude that the inhibitor treatment application has extended the service life of the structure by at least 10 years.

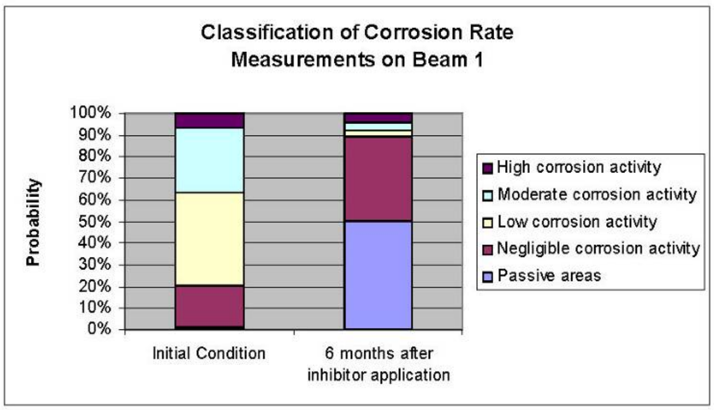


Figure 20. Corrosion activity before and after inhibitor application.

[7] Frølund, T., Jensen, F.M. & Bässler, R., "Determination of Reinforcement Corrosion Rate by Means of the Galvanostatic Pulse Technique," *First International Conference of Bridge Maintenance*, IABMAS 2002, Barcelona, Spain.
[8] K. Clear, "Measuring Rate of Corrosion of Steel in Field Concrete Structures," paper no. 88-0324, 68th Annual Transportation Research Board Meeting, 1989.

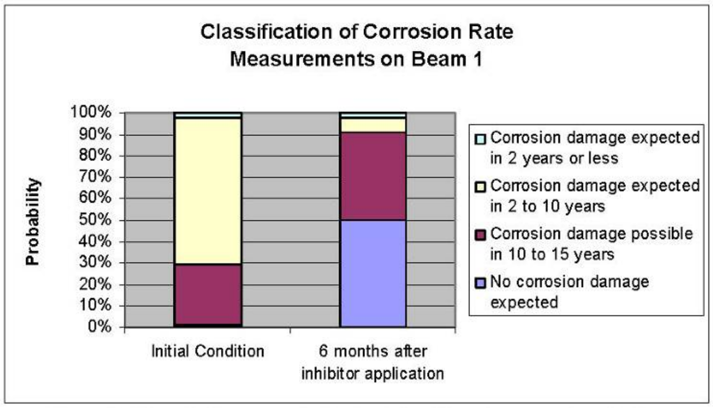


Figure 21. Corrosion damage projections for Beam 1 based on corrosion rate data.

Beam 2 – Galvanic Coating

The portion of the ring girder designated "Beam 2" had delaminated sections repaired and a NASA-developed sacrificial cathodic corrosion protection coating applied. Work was completed on this beam in early February, 2007. The galvanic coating is based on inorganic zinc chemistry but has been modified by replacing half of the zinc powder with equal amounts of aluminum and magnesium as well as trace amounts of indium to enhance electrochemical properties. An electrical current is generated between metallic particles in the applied coating and the surface of the steel rebar to provide cathodic protection to the rebar. The current forces a flow of electrons from the coating (anode) to the rebar along a separate metallic connection; this surplus of electrons at the rebar (cathode) prevents the loss of metal ions that would normally occur as part of the natural corrosion process

Figure 22 shows an overview of the beam during our July visit. The circular areas are where the coating has been ground away to facilitate corrosion rate and electrochemical potential measurements. These areas of missing coating should not impact the overall performance of the sacrificial coating. The applied coating had some thick areas, evidenced by visible cracking or sagging. Generally, the coating appeared to be well adhered and uniformly covered the concrete surface. Three titanium mesh strips are embedded in the coating lengthwise along the beam. These strips provide redundant collection points to be connected to the reinforcing steel. Figure 23 shows a closer view of the three mesh strips. The yellow wires provide electrical continuity between the mesh strips and the reinforcing steel.

Figure 22. Overview of Beam 2 with the NASA sacrificial coating applied.

Figure 23. Close up showing titanium mesh connections in sacrificial coating.

Water Transmission Tests – Beam 2 (Galvanic Coating)

Several water transmission tests were performed before the application of the galvanic coating. As the coating forms a barrier to water, it was not deemed appropriate to repeat these measurements after the coating application.

- The following results were observed using a Rilem Tube water transmission test:
  - Location A-5: 0.5 mL after 20 minutes
  - Location A-4: 0.4 mL after 20 minutes
  - Location A-3: 0.55 mL after 20 minutes (located on an area which had been wetted for the GalvaPulse measurements prior to the test).
- A water penetrability test was conducted on Beam 2 in accordance with ISO 7031 using GWT apparatus. The test was performed approximately 22 inches from the left end of the beam, 8 inches down from the top. This is in the vicinity of test location A-5. Water absorption occurred too quickly to get the pressure in the test chamber up to 1 psi. No surface cracks were apparent, but this rate of water adsorption suggests a fissure or void below the test area.

GalvaPulse Measurements – Beam 2 (Galvanic Coating)

On January 18, Surtreat personnel wetted the beam and covered it with plastic. Moisture was evident under the plastic in some areas when we arrived at approximately 0900 on January 20. On Beam 2, a grid was laid out with points on 12-inch centers from the right end of the beam. The leftmost points were 25 feet from the right support column. Rows were 3, 11, and 17 inches from the top of the beam. Contact was made on the exposed rebar located approximately 190 inches from the left end. Valid corrosion rate measurements were obtained at 75 locations before treatment. Unfortunately, the Galvapulse instrument cannot make measurements through a coating. In July (approximately 6 months after the inhibitor application), the coating was removed from four locations to facilitate Galvapulse measurements. Replicate data was taken at each location, providing 31 valid corrosion measurements. Reductions in both average and median corrosion rate were observed as shown in Table 3.

Table 3 - Beam 2 Corrosion Rate Measurements

	Before Treatment (January, 2007)	After Treatment (July, 2007)	Reduction
Median (50% probability)	204.2 μm/yr (8.04 MPY)	178 μm/yr (7.01 MPY)	13%
Average	234.5 μm/yr (9.23 MPY)	190.3 μm/yr (7.49 MPY)	19%

The cumulative probability plot in Figure 24 shows all of the corrosion rate measurements made before and after application of the galvanic coating. Note that the higher corrosion rate measurements seem to be suppressed, yet many corrosion rates remain high.

It was not possible to isolate the galvanic coating from the circuit during the Galvapulse measurements. Furthermore, it is not fully understood how the sacrificial system may impact the Galvapulse measurements. As a result, the corrosion rate measurements made after installation of the sacrificial coating may not accurately represent the change in corrosion rate due to the sacrificial coating.

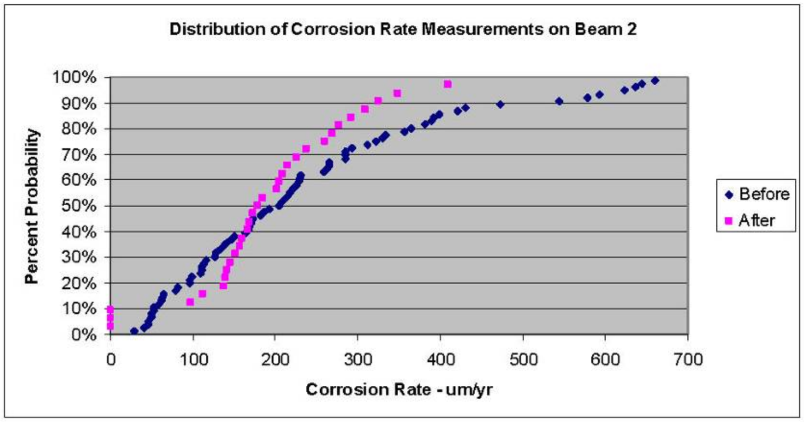


Figure 24. Probability distribution of corrosion rate measurements before and 6 months after cathodic coating application.

Sacrificial Coating Assessment – Beam 2 (Galvanic Coating)

The current flow between the sacrificial coating and the rebar needs to be measured along with the shift in potential when the coating is disconnected from the rebar to determine the effectiveness of the sacrificial coating. Neither of these measurements was particularly successful. This was due to the presence of a short between the coating and the rebar other than the installed bond wires. While such paths do not impact the effectiveness of the sacrificial coating, they do impact our ability to measure its impact.

In order to measure the current interchange between the anode and rebar, the two must be electrically isolated. Initially, very low resistances were measured between the anode and rebar. In particular, the resistance measured between the middle anode strip and the rebar was on the order of a milliohm. Removal of approximately 90 inches of this strip resulted in a resistance increase to approximately 65 ohms. The resistances between the top anode strip and the rebar was approximately 430 ohms. The resistance between the bottom anode strip and the rebar was approximately 40 ohms.

Using a handheld multimeter, very low current values on the order of tens of microamps were measured from each anode bus to the reinforcing steel. When the anode was wetted, the current flow increased by an order of magnitude. This indicates that the sacrificial coating is supplying

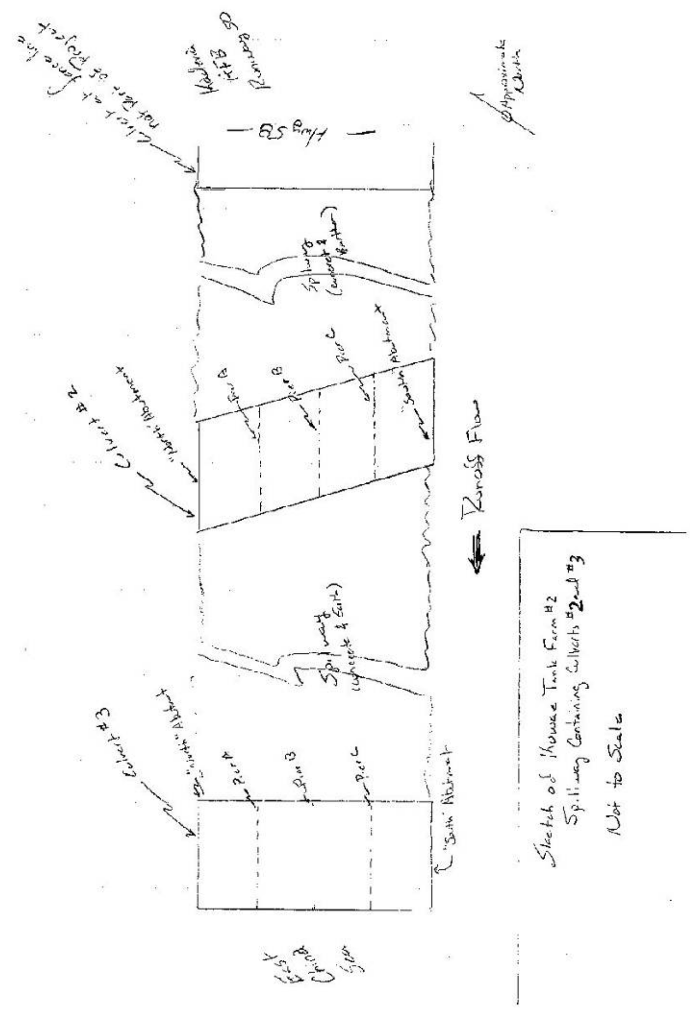
current to the reinforcing steel and the current reacts as would be expected to a change in the concrete resistance (imparted by wetting the concrete).

The potential response of the reinforcing steel to changes in the sacrificial current was negligible. In the dry and wet conditions, the potential of the reinforcing steel was measured relative to a copper/copper-sulfate reference. No potential response was observed when the anodes were connected and disconnected. Furthermore, the "disconnected" potentials of the anode and reinforcing steel were not substantially different. A difference in potential between the anode and cathode is required for the sacrificial corrosion mechanism to be effective. However, all of this potential behavior would be consistent with an electrical short between the anode and the reinforcing steel.

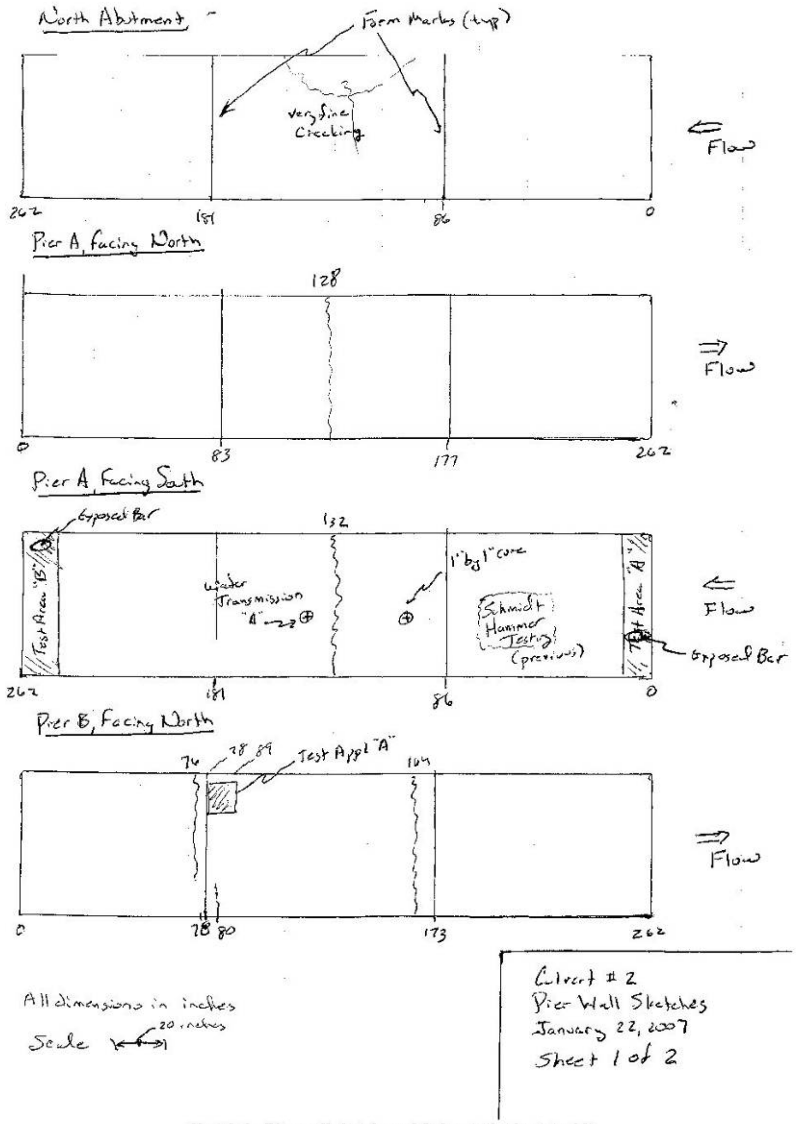
Additional characterization of the galvanic coating system would have required removal of additional lengths of titanium mesh anode bus. Even with the significant effort required to essentially disassemble and reassemble the system, there was no guarantee that the coating could be effectively isolated. As a result, it was decided to conclude the testing at this point. For a longer-term evaluation of the corrosion control provided by the coating, the presence of additional shorts is not an issue. Thus, we still have the ability to demonstrate the benefits of the coating in the future.

In summary, several tests were performed to quantify the performance of the sacrificial coating. The data are consistent with an effective cathodic protection system which is internally shorted to the reinforcing steel. This means that the external (wire) connections are in parallel with a metallic connection through the concrete (perhaps via a wire staple or anchor). Attempts to remove the short were somewhat successful, but stopped to avoid excessive damage to the test system. While the short will not impact the performance of the system, it does interfere with the measurements which are made to validate that the system is working. The observations support the conclusion that the sacrificial coating is protecting the reinforcing steel. However, we were not able to make measurements to quantify the degree of protection which is being provided.

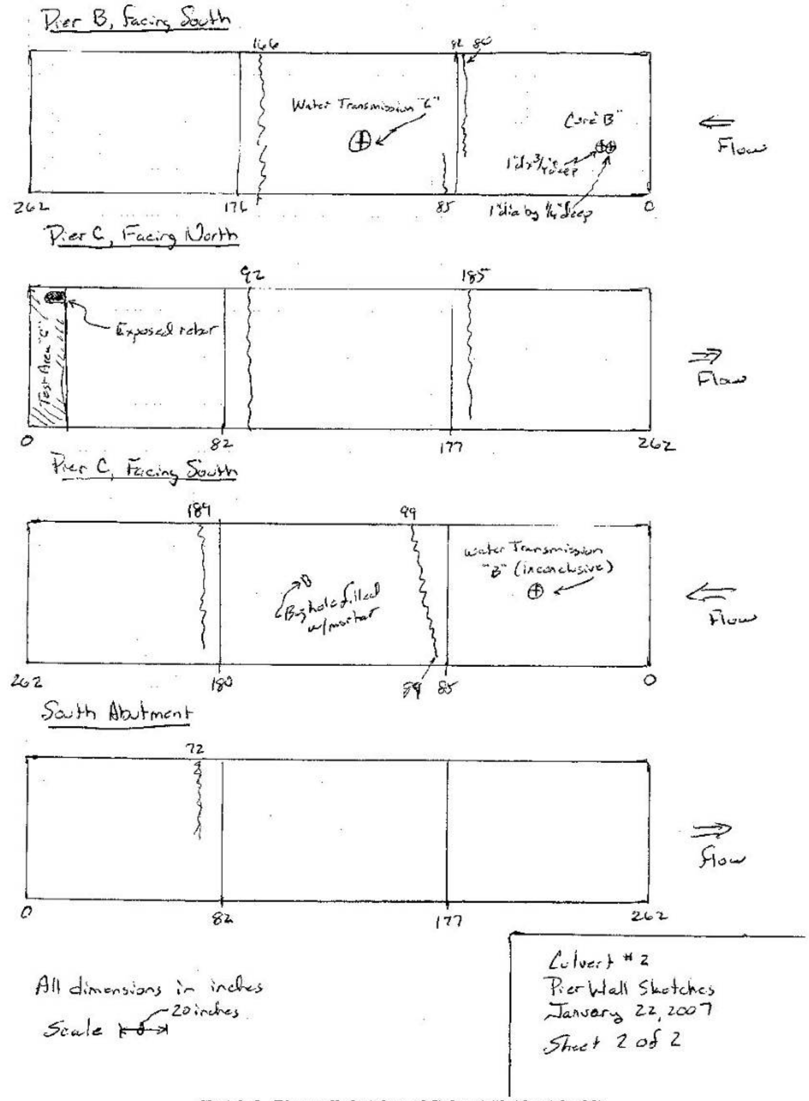
Appendix A – Sketches of the Structures



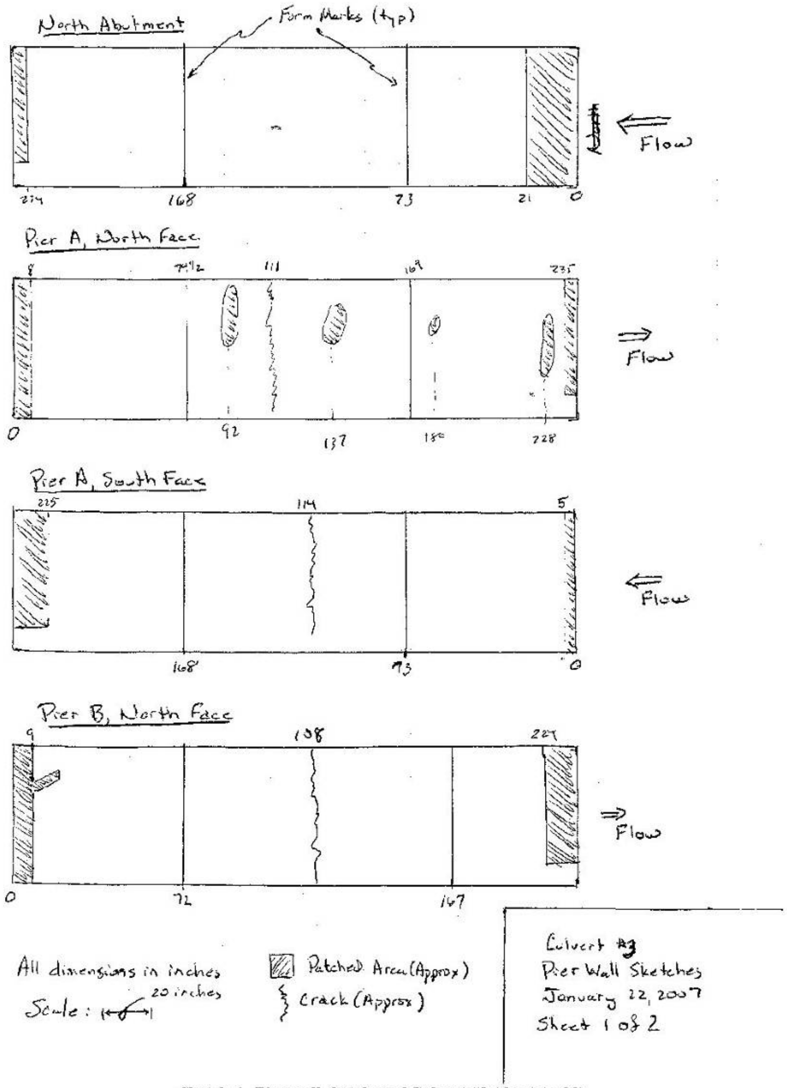
Sketch 1. Overview of the spillway containing Culverts #2 and #3.



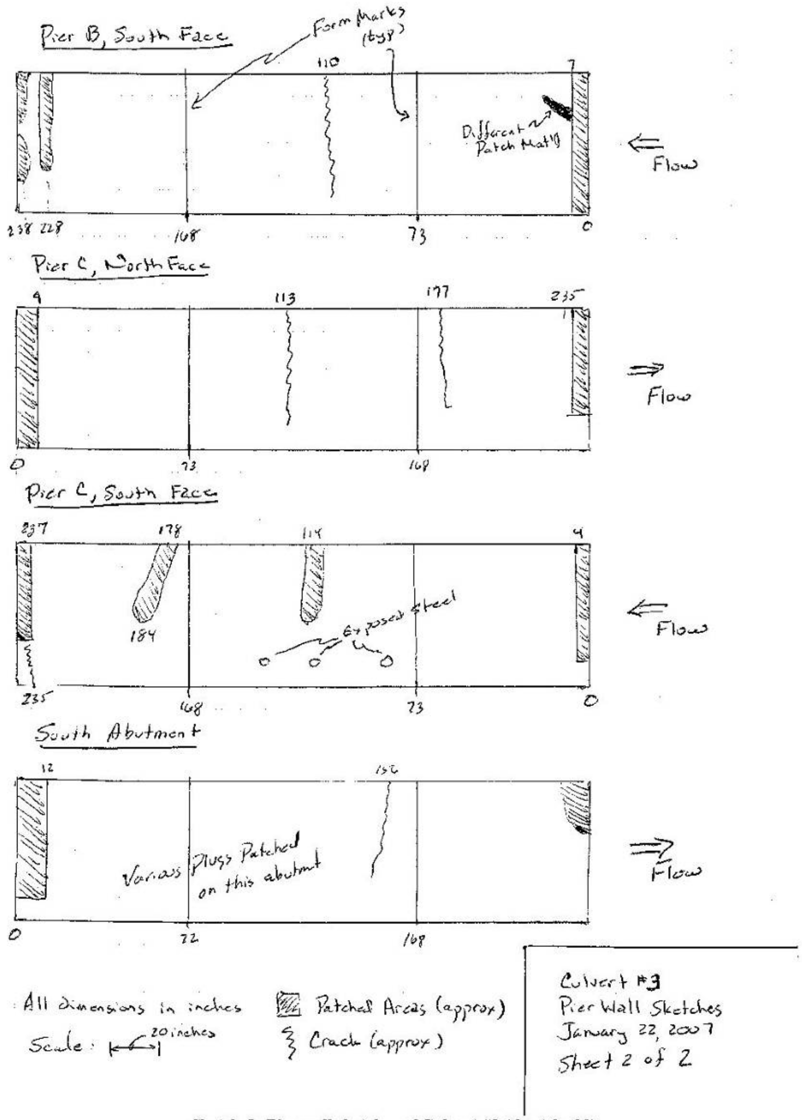
Sketch 2. Pier wall sketches of Culvert #2 (sheet 1 of 2).



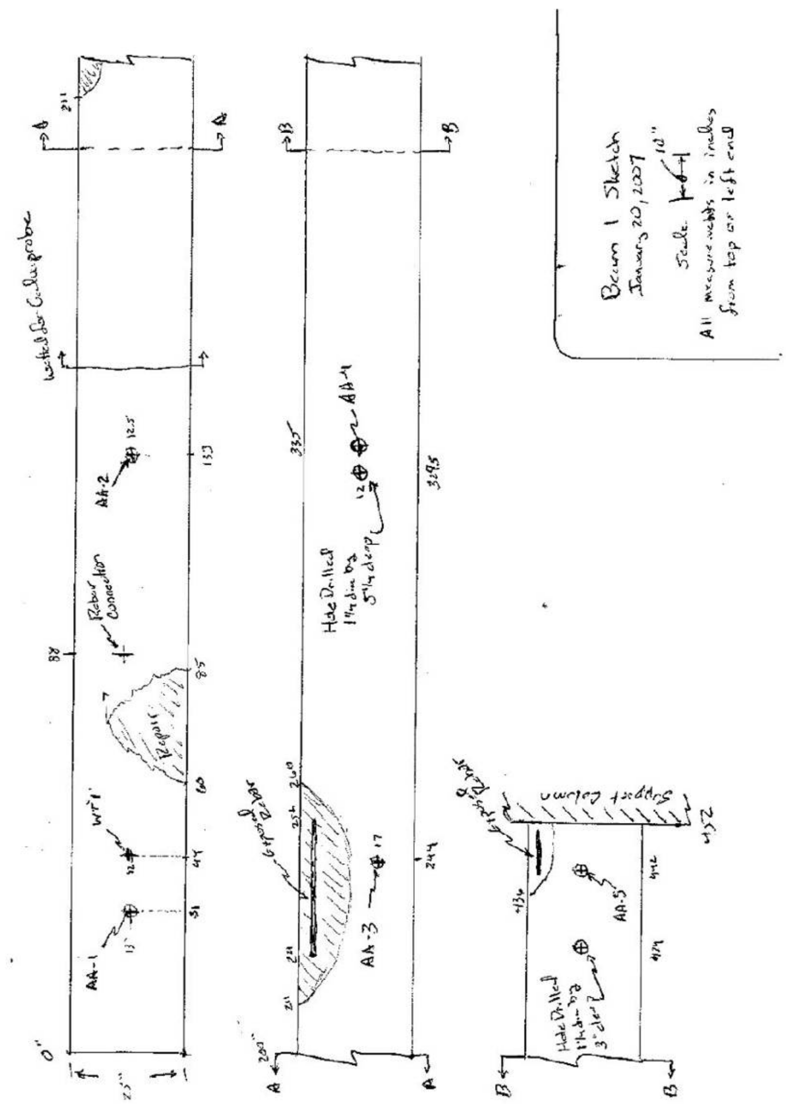
Sketch 3. Pier wall sketches of Culvert #2 (sheet 2 of 2).



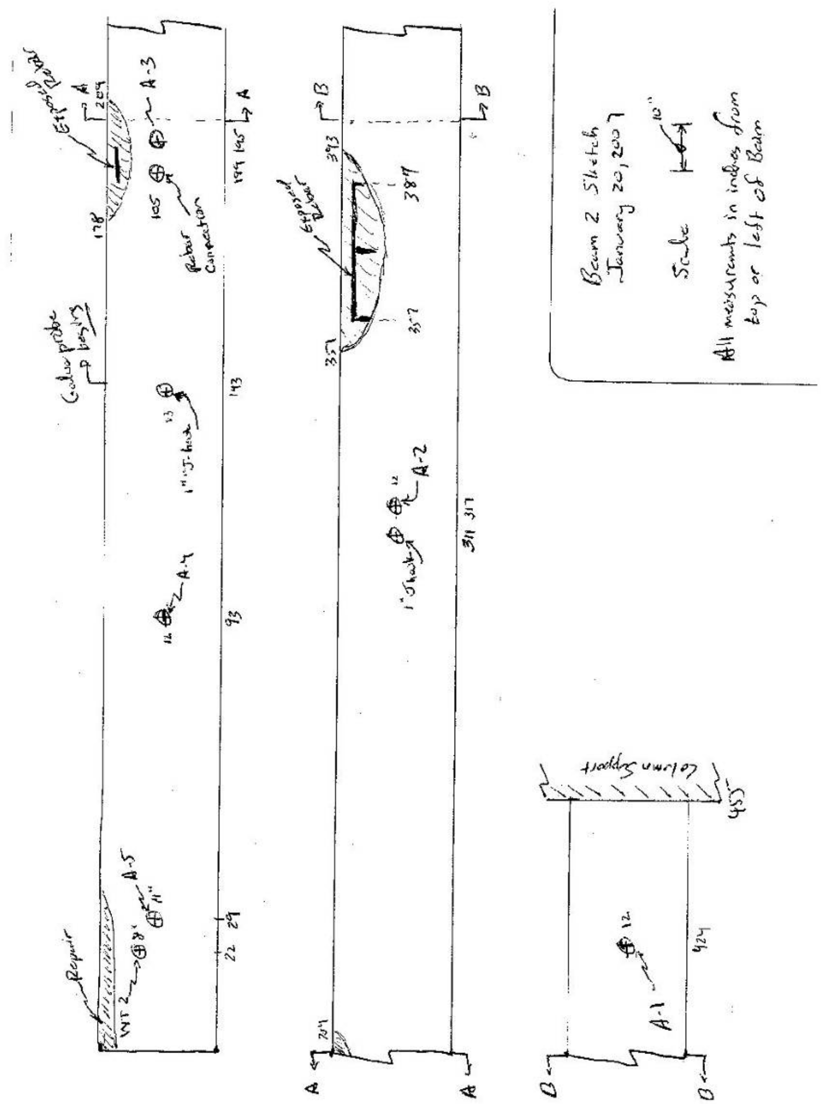
Sketch 4. Pier wall sketches of Culvert #3 (sheet 1 of 2).



Sketch 5. Pier wall sketches of Culvert #3 (sheet 2 of 2).



Sketch 6. Beam 1.



Sketch 7. Beam 2.

Appendix D: Bushman & Associates Contract Report

QUALITY CONTROL INSPECTIONS FOR CORROSION PREVENTION AND CONTROL PROJECTS (CPC) AT MULTIPLE ARMY INSTALLATIONS

Prime Contract: W9132T-06-D-0001
06T0147 Task; Related Prime Order: 0013

Concrete Beams at Naha Port, Okinawa, Japan

Draft Final Report

Version 1.20

Prepared for

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November 2007

Concrete Beams at Naha Port, Okinawa, Japan

Background

Okinawa is a severely corrosive environment due to its highly corrosive soil and hot and humid weather. Deterioration of the concrete due to rebar corrosion was identified as a potential problem on the walls of a warehouse at Naha Port that is used for storage of supplies for all of the US Armed forces in the Pacific Theater. Without proper attention, rebar in concrete is susceptible to corrosion, especially in chloride-containing environments such as typically encountered in marine atmospheres. The corrosion products of the steel reinforcement are ~ 3 times the volume of the corroding steel rebar; this creates a very substantial tensile force on the concrete (which is intrinsically a weak material in tension), causing it to crack and spall. A concrete structure weakened by this mechanism often necessitates large-scale structural repairs. Corrosion protection for the rebar can be established through the use of a variety of concrete restoration and protection systems. One type of corrosion mitigation is based on the premise that the deterioration of Portland cement concrete is largely a chemical process which can be inhibited and reversed. Based on this approach, Surtreat Holding LLC (Surtreat; Pittsburgh, PA) has reportedly developed a product for rehabilitating steel-reinforced concrete structures. The concrete surface is subjected to chemical treatment that endeavors to penetrate the concrete microstructure in liquid and vapor state, combines with the cement phase, and "deposits" on the steel reinforcement. This treatment is believed to increase the ability of concrete to resist deterioration by increasing compressive strength, reducing permeability, inhibiting corrosion of the reinforcing steel components and improving concrete's resistance to acid attack.

Surtreat was tasked by CERL to apply its treatment system to two concrete beams located inside building No. 306 at Naha Port (Okinawa). The steel-reinforced beams were reportedly constructed circa 1951. Surtreat visited the job site in November 2007 to assess the initial condition of the concrete beams; reportedly, Surtreat's evaluation consisted of half-cell potential measurements of the rebar, corrosion rate measurements of the rebar with the aid of a commercial instrument called the Galvapulse© probe, and water-permeability measurements of the concrete using 100 psi pressure. In January? 2007, Surtreat visited the site again and applied two types of treatments, one to each of the subject concrete beams.

Under Task 3 of the Mandaree contract, Bushman & Associates (B&A) was tasked by CERL to independently insure compliance by Surtreat with the Government's Scope of Work.

Task 3

Bushman & Associates visited the job site at Naha Port twice. The first visit was made in December 2006 after Surtreat's initial-condition assessment. The second visit was made in August 2007, approximately 7 months after application of the treatments to the concrete beams by Surtreat.

Inspections and Measurements Performed by B&A

Visual Inspection

During B&A's initial site evaluation, the concrete beam immediately to the right of the main entrance door was designated "AA"; and the beam to the right of "A" was designated "A", as illustrated in Figure 1a. The before-treatment appearance of the subject beams in building No. 306 documented photographically is depicted in Figures 1b – 1c. Visually beam "AA" appeared to be in quite good condition. Beam "A" appeared to have had quite a number of repair patches; however, there was no evidence of spalling, widespread cracking, or significant rust staining on either beam. It is not known if the "repair" patches observed on the surface of beam "A" were related to previous corrosion.

According to Surtreat, beam "AA" was then treated with both vapor-penetrating inhibitor and migrating liquid inhibitor; while beam "A" was coated with a zinc-aluminum-indium-rich paint system in January? 2007. Surtreat reported that this coating system was developed by Jim Nichols (NASA, Kennedy Space Center, Florida). This second system presumably is intended to serve as a galvanic anode system to provide cathodic protection for the underlying rebar. Some round patches were left uncoated on beam "A" to allow measurement of potentials. The sketch in Figure 1d, created by B&A based on the information provided by Surtreat, shows small test leads attached to the rebar in both beams; as well as the titanium mesh strips to electrically connect the coating to the rebar. The photographs in Figures 1e – 1i show the actual after-treatment appearance of the beams.

Rebar Corrosion Potential

Half-cell potential measurements of the rebar were performed along both beams per ASTM (American Society for Testing Materials) Standard C-876, both before and 7 months after treatment of the beams by Surtreat. For the baseline measurements (i.e. before treatment), a rebar locator was used to find the rebar embedded in the beams. A hammer-drill was used to make a small hole in each beam to expose the rebar. Connection to the rebar was made by carefully driving a steel awl into the hole as shown in Figure 2a. The positive test lead of a DC digital voltmeter was connected to the awl. The negative lead of the voltmeter was connected to a $Cu/CuSO_4$ reference electrode (CSE) which was contained inside a special clear-plastic bottle with a hole in the bottom fitted with a sponge manufactured by the M. C. Miller Company specifically for measuring rebar potentials in concrete. The bottle was filled with distilled water containing a few drops of detergent solution. The slow "leak" of water from the bottom of the bottle wetted the sponge which was placed on the concrete surface as shown in Figure 2b. This provides an electrolyte bridge between the CSE and the moisture within the concrete enveloping the rebar. Tables 1 and 2 summarize the results of the rebar potential measurements made at periodic intervals along the span of each beam before and after treatment, respectively. These data are presented graphically in Figures 2c and 2d. It is apparent that the baseline (i.e. before treatment) potentials of the rebar in beam "AA" were consistently very noble indicating the steel to be in a "passive" condition.

After treatment, with a few exceptions, there was a negative potential shift of ~ 100 mV or more (shift in the active direction). However, even with this shift, the actual potentials are still considered to be "passive" according to ASTM Standard C-876.

For beam "A", the baseline (i.e. before treatment) potentials were consistently ~ 200 mV more negative than for beam "AA", but still considered "passive". After coating the beam with the zinc-aluminum-indium system, wide variations in the half-cell potentials were noted as shown in Figure 2d. At some locations, the potentials exhibited a negative shift of as much as 100 mV or more; while at other locations there was a noble shift of as much as 50 mV; and at some locations there was no significant change. B&A evaluated the average of the potentials measured before and after coating. This averaged data is as follows:

Average Potentials Measured on Bare Spots of Beam "A" before and after Coating with Zn/Al/In Metallic Coating		
Average along coated Beam A before Coating:	-116.0	mV
Average in all bare spots on Beam A (after Coating):	-78.5	mV
Average in bare spots on Beam A in large bare spots only (after Coating):	-104.7	mV
Average along coated Beam A" (after Coating):	-120.4	mV

This data indicates there is no substantial change in the potentials measured before and after treatment.

With the zinc-aluminum-indium coating system, a consistently large potential shift to cathodic protection potentials (e.g. negative ~ 900 mV) would have been have expected (at least in the values measured in the bare spot windows provided by Surtreat) if sufficient chloride-containing moisture was present in concrete. The measured potentials are ambiguous; e.g. the positive shifts in Figure 2d could be related to the potential of the titanium mesh strip installed by Surtreat (to provide continuity between the coating and the rebar); the negative shifts could indicate some degree of cathodic polarization by the coating where limited moisture was present; no significant shifts in potential could indicate low moisture levels at those areas. The potentials measured at the areas left intentionally uncoated were also quite variable as shown in Appendix 1.

CERL had specified that the "reduced rebar corrosion potential per ASTM Standard C-876 shall show a reduced voltage by 70% in 14 days". It is presumed that this statement means a 70% potential shift in the noble (more positive) direction as a result of the inhibitor treatment. Figure 2c shows that there was in fact a negative shift in potential after inhibitor treatment and a positive shift only at a few spots for the coated beam. It is important to understand, however, that the potential values measured either before or after treatment were not indicative of active corrosion on the rebar in either case per ASTM Standard C-876 criteria.

Water Penetration Reduction Test

CERL had specified a water penetration reduction test with the following criteria: (i) 100% resistance after 14 days exposure to 6-inch column of water, (ii) 75% resistance

after 28 days exposure to 6-inch column of water, and (iii) 90% resistance after 24 hours when 100 psi is applied. Discussions with several experts on water penetration tests on concrete indicated that the 100 psi test was very difficult to perform in practice because of the difficulty of maintaining a water-tight seal for 24 hours. In view of this, B&A performed the water penetration test using RILEM© tubes as recommended by CERL's consultant at Cape Kennedy, Florida.

RILEM tubes were attached with putty at several locations along each beam. A typical tube mounted on beam "A" is shown in Figure 3a. The tubes were carefully filled with distilled water and the rate of water penetration into the concrete measured by recording the meniscus level periodically. In some instances, leaks were observed between the tubes and the concrete surface. In such cases, the tubes were removed and resealed at slightly different locations. Leaking tubes became a major problem when attempting water penetration measurements on the after-treated concrete surface of beam "AA". Repeated attempts were made to reseal the tubes with limited success. It is conjectured that the inhibitor treatment produced a "waxy" surface which interfered with sealing of the tubes to the concrete.

The water penetration test data before and after inhibitor treatment of beam "AA" are shown graphically in Figures 3b and 3c, respectively. As stated above, the after-treatment data for this beam are very limited due to the problems encountered with obtaining water-tight seals. This limited data show a notable apparent reduction in water penetration rate. For beam "A", the before and after-coating water penetration data are shown in Figures 3d and 3e, respectively. The data show widespread scatter for the coated beam, indicating that penetration rate at some areas was ostensibly reduced but seemingly unaffected at others. It can be argued that CERL's criterion of "100% resistance after 14 days" was met for beam "AA" but not beam "A".

All of the water penetration data as well as half-cell potential data collected during the two site visits are included in Appendix 1.

Discussion

As indicated earlier, the subject beams appeared to be in relatively good condition even before the inhibitor and coating treatment by Surtreat. The visual observations were supported by the half-cell corrosion potential measurements which indicated relatively "passive" potentials for steel in concrete. Based on this, the probability of corrosion even before inhibitor treatment is low as depicted graphically in Figure 4. This is corroborated by the low corrosion rates for the rebar determined by Surtreat in November 2007, using the Galvapulse probe. Although the water penetration tests indicated the concrete beams to be quite permeable, there is no acceptance criterion for this test pertaining to probability of corrosion of the rebar – for example analogous to ASTM Standard C-876 which allows delineation of corrosion probability based on half-cell potentials.

Conclusions

Visual appearance of the concrete test beams in building 306 at Naha Port (Okinawa) and half-cell potential measurements (per ASTM Standard C-876) indicated that the probability of corrosion on the embedded rebar was low; even before the beams were subjected to any treatment. Thus, the effectiveness of the inhibitor treatment applied to the surface of concrete beam "AA" and zinc-aluminum-indium coating applied to the surface of beam "A" to mitigate rebar corrosion in both beams could not be ascertained unambiguously. The short-term water penetration tests performed using RILEM tubes indicated that the CERL criterion of 100% resistance after 14 days was met on beam "AA" but could not be met on beam "A".

Recommendations

It is B&A's understanding that other structure in Okinawa were provided with Surtreat protection systems. Hopefully these structures were experiencing more active corrosion prior to treatment application so that better comparative analysis (before and after treatment) could be made. To more fully analyze these treatment methods effectiveness, one or two concrete structures at southern coastal continental U.S. Army facilities where severe corrosion of the rebar is being experienced should be selected. The severe-corrosion condition should be verified by a combination of methods such as visual (i.e. after exposing representative areas of the rebar), half-cell potentials, and corrosion rate measurements; e.g. using linear polarization resistance (LPR) and/or electrical resistance (ER) probes buried in the concrete. When using LPR probes, the counter electrode also needs to be buried in the concrete to determine the effectiveness of any penetrating treatment subsequently applied to the surface of the concrete. While placing the counter electrode on the surface of the concrete is convenient for making measurements on embedded rebar, results on treatment effectiveness can be misleading because of resistance effects introduced in the electrolyte path by all treatments which generate polarizing currents.

Acknowledgements

B&A would like to acknowledge the assistance and support provided by Ms. Clara Allen and MS. Shiho Ishihara at NAHA Port.

Table 1. Half-cell potentials of rebar in beam "AA" before and after inhibitor treatment

Distance from left side of beam, ft	Half-cell potential (vs. $Cu/CuSO_4$), before treatment, mV	Half-cell potential (vs. $Cu/CuSO_4$), after treatment, mV
0.5	76	33
2.5	137	121
5	142	70
7.5	153	33
10	183	173
12.5	177	30
17	191	12
17.5	176	20
20	132	92
22.5	120	-76
25	64	-52
27.5	128	-35
30	121	-34
32.5	120	-37
35	101	-24
37.5	92	-44
40	15	-64
40.5	75	-105

Table 2. Half-cell potentials of rebar in beam "A" before and after zinc-aluminum-indium-rich coating application

Distance from left side of beam, ft	Half-cell potential (vs. $Cu/CuSO_4$), before coating, mV	Half-cell potential (vs. $Cu/CuSO_4$), after coating, mV
1	- 111	- 94
3	- 124	- 97
5	- 83	- 215
7	- 84	- 10
9	- 65	- 36
11	- 95	- 29
13	- 72	- 280
15	- 54	- 55
17	- 111	- 58
19	- 111	- 113
21	- 107	- 102
23	- 112	- 47
25	- 119	- 63
27	- 148	- 103
29	- 159	- 331
31	- 164	- 349
33	- 162	- 123
35	- 159	- 104
37	- 143	- 134
39	- 136	- 65

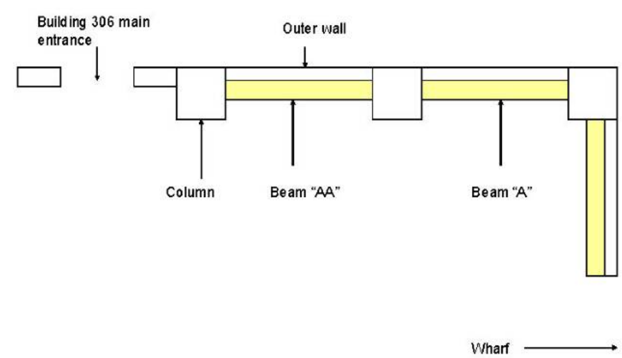

Figure 1a. Plan view of concrete beams "A and "AA" in building 306, Naha Port, Okinawa

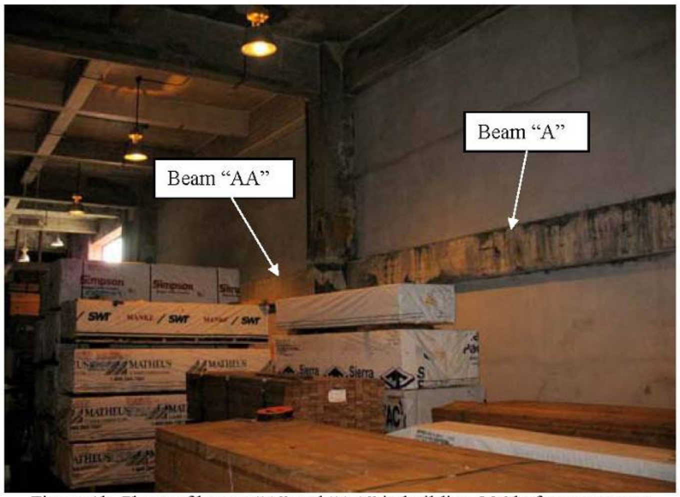

Figure 1b. Photo of beams "A" and "AA" in building 306 before treatment

Figure 1c. Closer view of beams "A" before treatment

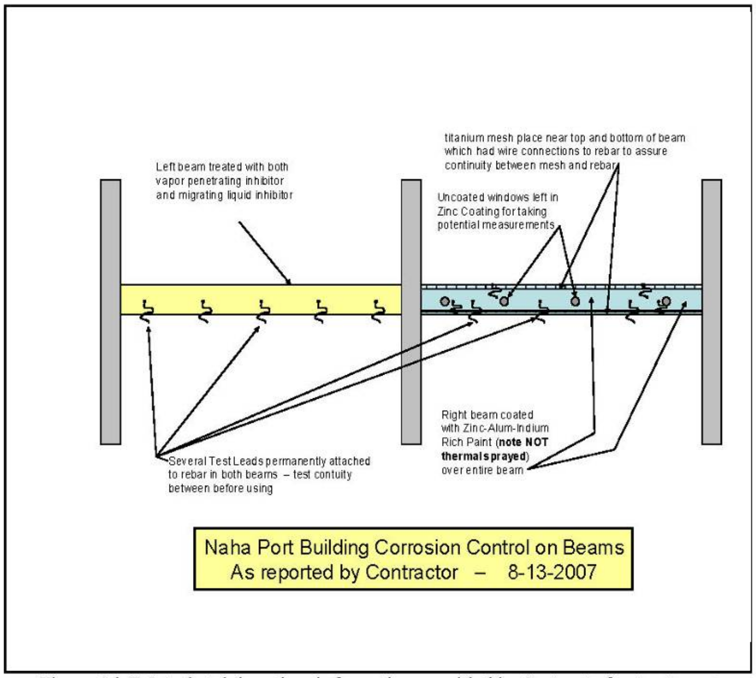

Figure 1d. B&A sketch based on information provided by Surtreat after treatment of the concrete beams; beam "AA" is on the left (yellow) and beam "A" is on the right (blue)

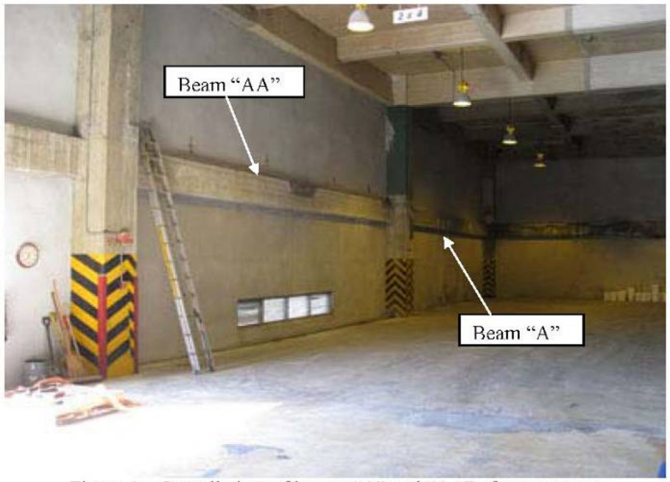

Figure 1e. Overall view of beams "A" and "AA" after treatment

Figure 1f. Overall view of beam "AA" after treatment; reportedly treatment consisted of vapor and liquid inhibitor application to the concrete beam surface

Figure 1g. Overall view of beam "A" after treatment; reportedly a zinc-aluminum-indium rich coating was applied to the concrete beam surface

Figure 1h. Closer view of coated beam "A"; note Ti mesh strips, embedded test lead wires, and uncoated rectangular patch

Figure 1i. Closer view of beam "A: showing additional uncoated round patches

Figure 2a. Photo showing steel awl connection to rebar in beam "A" before treatment

Figure 2b. Measurement of rebar half-cell corrosion potentials on beam "AA" using a copper/copper-sulfate reference electrode before treatment

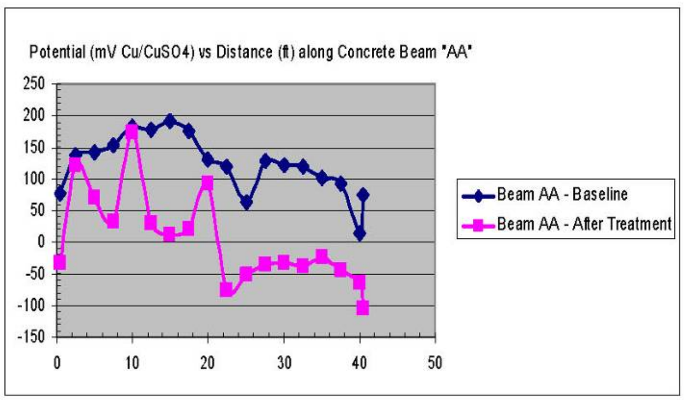

Figure 2c. Rebar half-cell potentials as a function of distance along beam "AA" before and after treatment

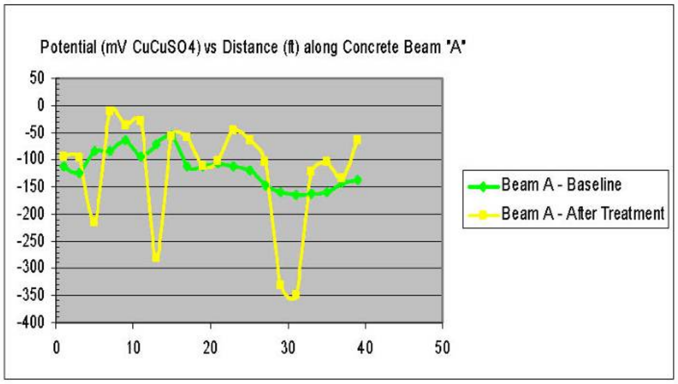

Figure 2d. Rebar half-cell potentials as a function of distance along beam "A" before and after treatment

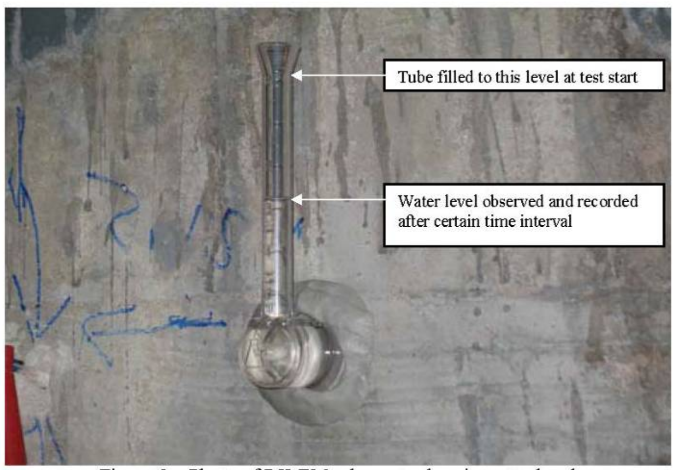

Figure 3a. Photo of RILEM tube; note drop in water level

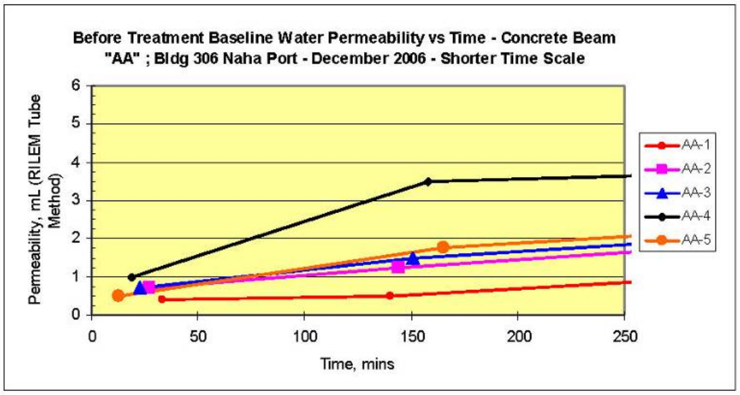

Figure 3b. Water penetration rate for beam "AA" before inhibitor treatment

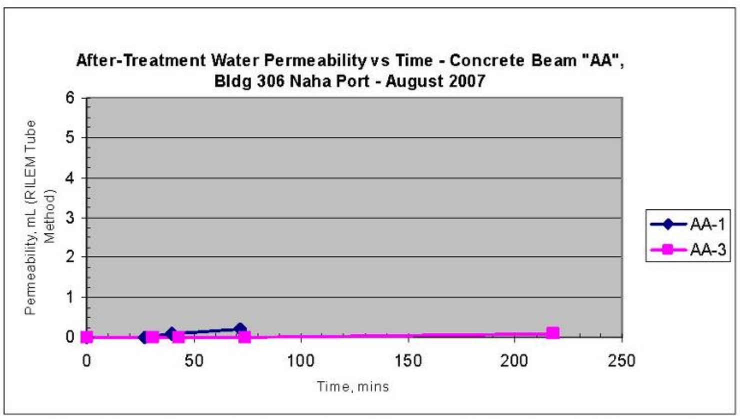

Figure 3c. Water penetration vs. time for beam "AA" after inhibitor treatment; data are limited because repeated attempts to seal RILEM tubes at other locations on beam "AA" were unsuccessful

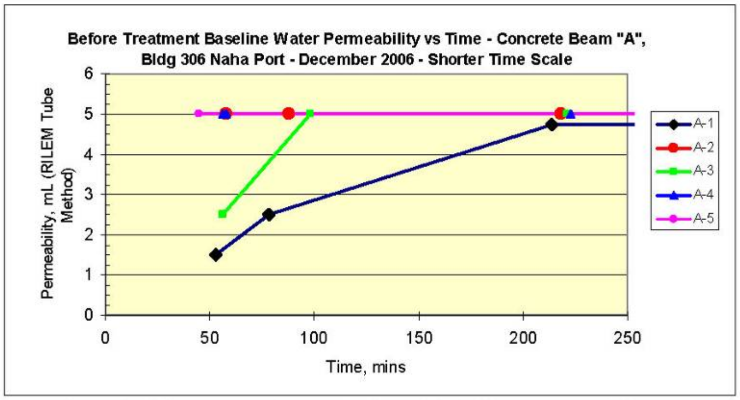

Figure 3d. Water penetration rate for beam "A" before coating application

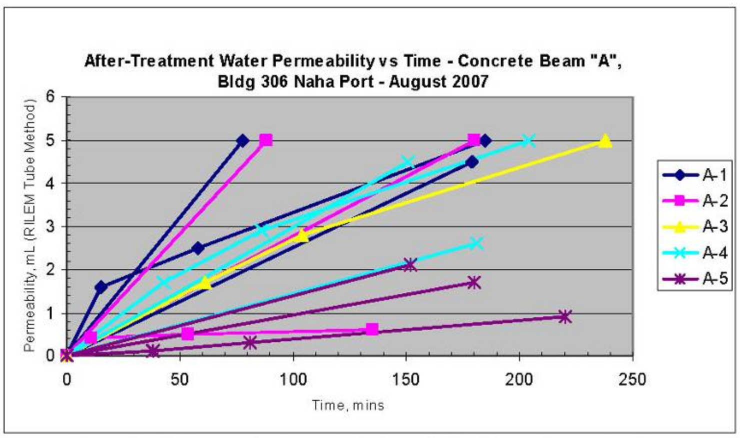

Figure 3e. Water penetration rate for beam "A" after coating application

Appendix 1

Spreadsheet containing before- and after-treatment half-cell potential and water penetration data collected by B&A during the two site visits to Naha Port

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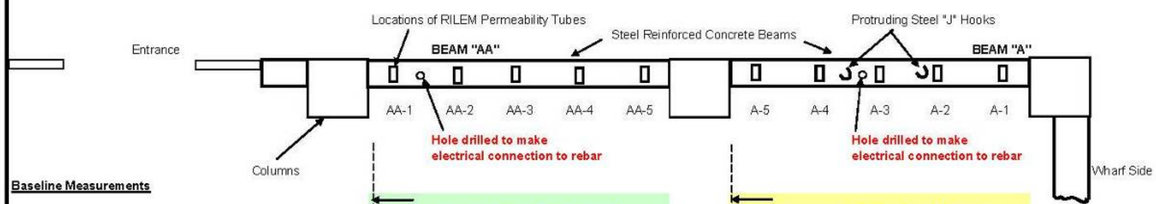
B&A QA Report on Concrete Beam Corrosion Control Project at Naha Port, Okinawa, Japan

Rebar Potentials vs Cu/CuSO4 half cell



Baseline Measurements

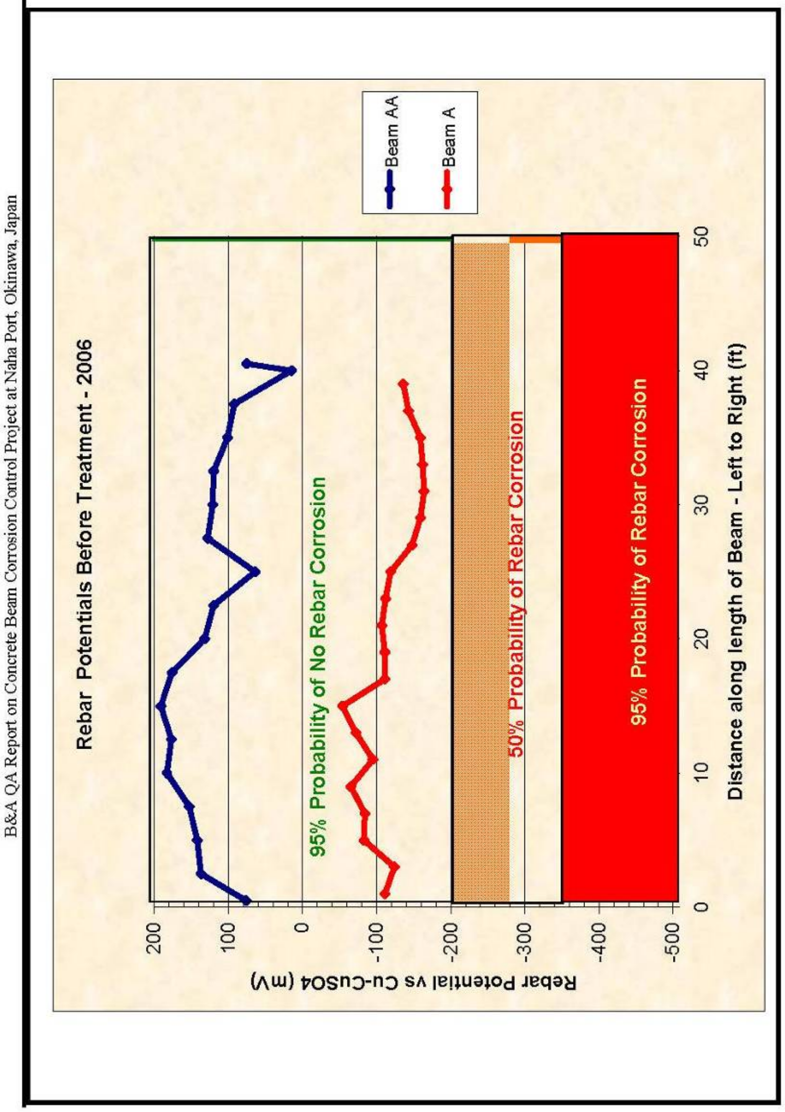
Thu, Dec 14, 2006

Potentials measured starting from this end

Approx Location (ft)		Potential (mV) vs Cu/CuSO4
0.5	6" from end	76
2.5		137
5		142
7.5		153
10	1' left of AA-2	183
12.5	1.5' right of AA-2	177
15		191
17.5	left of AA-3	176
20	right of AA-3	132
22.5		120
25		64
27.5		128
30	left of AA-4	121
32.5	right of AA-4	120
35		101
37.5		92
40	left of AA-5	15
40.5	right of AA-5	75

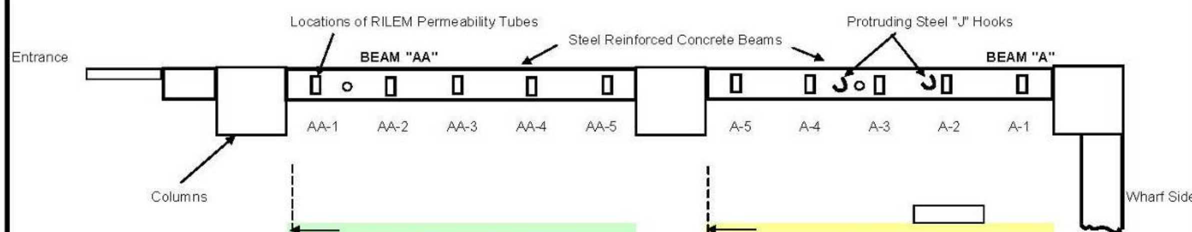
Potentials measured starting from this end

Approx Location (ft)		Potential (mV) vs Cu/CuSO4
1		-111
3		-124
5		-83
7	left of A-4	-84
9		-65
11	6" left of left J hook	-95
13	2' right of left J hook	-72
15	left of A-3	-54
17	2' right of A-3	-111
19		-111
21		-107
23	2' left of A-2	-112
25	left of right J hook	-119
27		-148
29		-159
31		-164
33		-162
35		-159
37	left of A-1	-143
39	6" from corner	-136



Rebar Potentials Before Treatment - 2006
Rebar Potential vs Cu-CuSO4 (mV)
200
100
0
-100
-200
-300
-400
-500
0
10
20
30
40
50
Distance along length of Beam - Left to Right (ft)
Beam AA
Beam A
95% Probability of No Rebar Corrosion
50% Probability of Rebar Corrosion
95% Probability of Rebar Corrosion

B&A QA Report on Concrete Beam Corrosion Control Project at Naha Port, Okinawa, Japan



Potentials measured starting from this end

Distance (ft)	Approx Location	Potential (mV) vs Cu/CuSO4 Before treatment (Dec '06)	After treatment (Aug '07)
0.5	6" from end	76	-33
2.5		137	121
5		142	70
7.5		153	33
10	1' left of AA-2	183	173
12.5	1.5' right of AA-2	177	30
15		191	12
17.5	left of AA-3	176	20
20	right of AA-3	132	92
22.5		120	-76
25		64	-52
27.5		128	-35
30	left of AA-4	121	-34
32.5	right of AA-4	120	-37
35		101	-29
37.5		92	-44
40	left of AA-5	15	-64
40.5	right of AA-5	75	-105

Beam AA

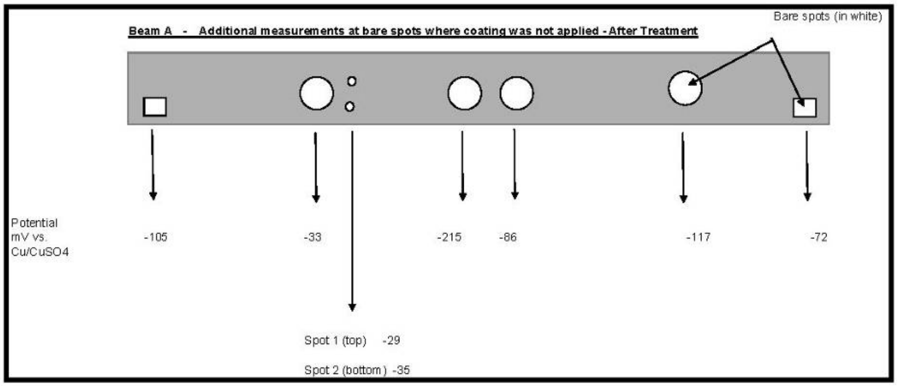
Treated with Surtreat migrating inibitor

Potentials measured starting from this end

Distance (ft)	Approx Location	Potential (mV) vs Cu/CuSO4 Before treatment (Dec '06)	After treatment (Aug '07)
1		-111	-94
3		-124	-97
5		-83	-215
7	left of A-4	-84	-10
9		-65	-36
11	6" left of left J hook	-95	-29
13	2' right of left J hook	-72	-280
15	left of A-3	-54	-55
17	2' right of A-3	-111	-58
19		-111	-113
21		-107	-102
23	2' left of A-2	-112	-47
25	left of right J hook	-119	-63
27		-148	-103
29		-159	-331
31		-164	-349
33		-162	-123
35		-159	-104
37	left of A-1	-143	-134
39	6" from corner	-136	-65

Beam A

Treated with Al-Zn-In coating



Continuity tests

Beam - A: All yellow leads embedded in concrete by Surtreat exhibited continuity with each other and the rebar

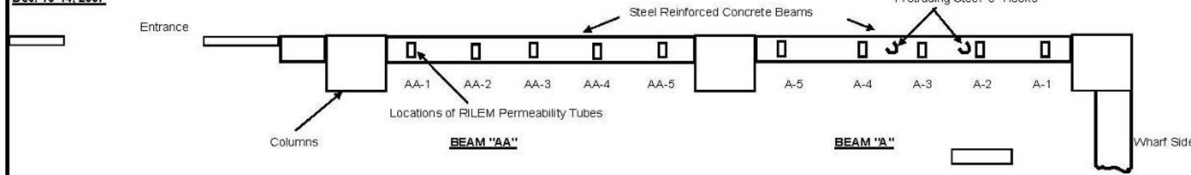
Beam AA - Yellow leads exhibited continuity; assumed to be connected to rebar

Rebar in beam A not continuous with rebar in beam AA

B&A QA Report on Concrete Beam Corrosion Control Project at Naha Port, Okinawa, Japan

NAHA Port - Water Permeability Tests on Girder Ring Beams Using RILEM Tubes

Dec. 13-14, 2007



Location	Day/Date	Actual Time	Action	Elapsed Time, min	Amount of Water Permeation, mL
AA-1	12/13/06	3:55 p.m.	Tube filled		
	12/13/06	4:28 p.m.		33	0.4
	12/14/06	9:56 a.m.		1141	3.75
AA-2	12/13/06	4:02 p.m.	Tube filled		
	12/13/06	4:29 p.m.		27	0.7
	12/14/06	9:54 a.m.		1139	>5
AA-3	12/13/06	4:07 p.m.	Tube filled		
	12/13/06	4:30 p.m.		23	0.7
	12/14/06	9:53 a.m.		1138	>5
AA-4	12/13/06	4:12 p.m.	Tube filled		
	12/13/06	4:31 p.m.		19	1
	12/14/06	9:47 a.m.		1132	>5
AA-5	12/13/06	4:19 p.m.	Tube filled		
	12/13/06	4:32 p.m.		13	0.5
	12/14/06	9:45 a.m.		1130	>5

Location	Day/Date	Actual Time	Action	Elapsed Time, min	Amount of Water Permeation, mL
A-1	12/13/06	3:05 p.m.	Tube filled		
	12/13/06	4:23 p.m.		78	2.5
	12/14/06	9:43 a.m.		1128	>5
A-2	12/13/06	2:55 p.m.	Tube filled		
	12/13/06	4:23 p.m.		88	>5
	12/14/06	9:43 a.m.		1128	>5
A-3	12/13/06	2:45 p.m.	Tube filled		
	12/13/06	4:22 p.m.		98	>5
	12/14/06	9:42 a.m.		1127	>5
A-4	12/13/06	3:25 p.m.	Tube filled		
	12/13/06	4:21 p.m.		56	>5
	12/14/06	9:41 a.m.		1126	>5
A-5	12/13/06	3:35 p.m.	Tube filled		
	12/13/06	4:20 p.m.		45	>5
	12/14/06	9:40 a.m.		1125	>5

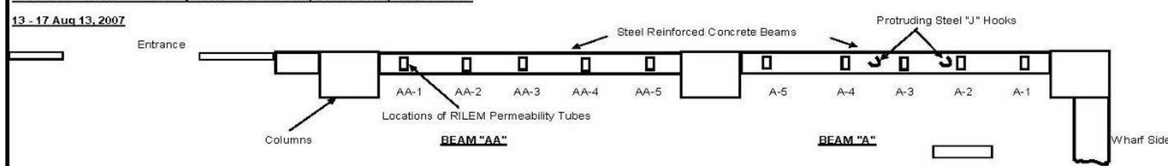
Location	Day/Date	Actual Time	Action	Elapsed Time, min	Amount of Water Permeation, mL
AA-1	12/14/06	9:58 a.m.	Tube refilled		
		1:40 p.m.		140	0.5
AA-2	12/14/06	9:55 a.m.	Tube refilled		
		1:41 p.m.		144	1.25
AA-3	12/14/06	9:53 a.m	Tube refilled		
		1:46 p.m.		151	1.5
AA-4	12/14/06	9:47 a.m.	Tube refilled		
		1:47 p.m.		158	3.5
AA-5	12/14/06	9:45 a.m.	Tube refilled		
		1:52 p.m.		165	1.75

Location	Day/Date	Actual Time	Action	Elapsed Time, min	Amount of Water Permeation, mL
A-1	12/14/06	10:23 a.m.	Tube refilled		
		11:19 a.m.		53	1.5
		1:57 p.m.		214	4.75
A-2	12/14/06	10:19 a.m.	Tube refilled		
		11:17 a.m.		58	>5
		1:57 p.m.		218	>5
A-3	12/14/06	10:16 a.m.	Tube refilled		
		11:12 a.m.		56	2.5
		1:57 p.m.		221	>5
A-4	12/14/06	10:12 a.m.	Tube refilled		
		11:10 a.m.		58	>5
		1:55 p.m.		223	>5
A-5	12/14/06	10:00 a.m.	Tube refilled		
			Cell Leaking - Abandoned		

B&A QA Report on Concrete Beam Corrosion Control Project at Naha Port, Okinawa, Japan

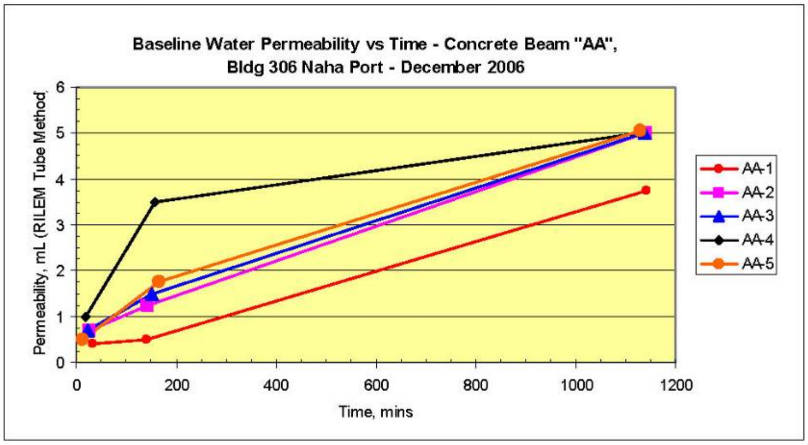
NAHA Port - Water Permeability Tests on Girder Ring Beams Using RILEM Tubes

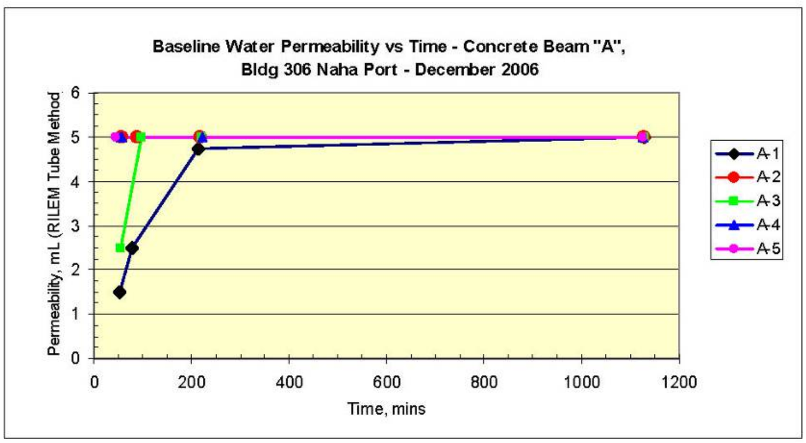
13 - 17 Aug 13, 2007

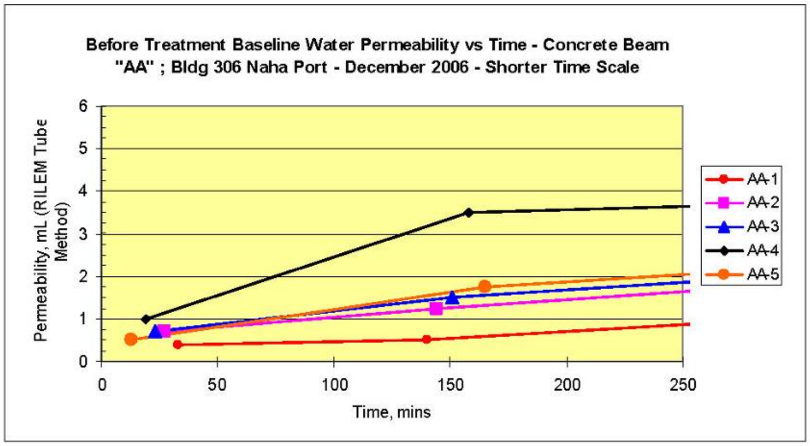


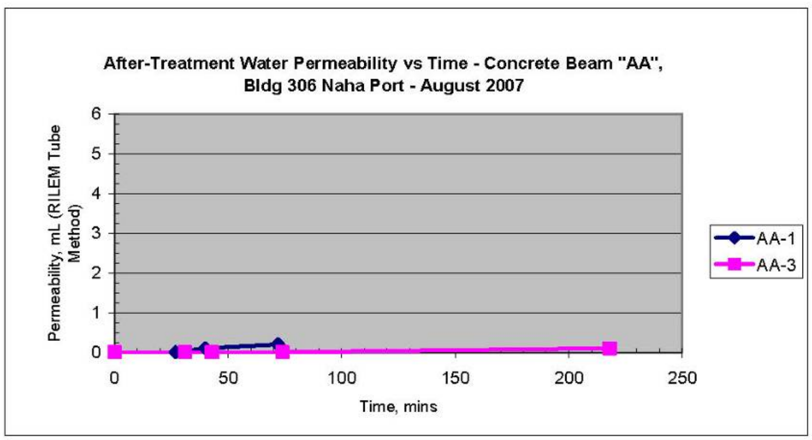
Location	Day/Date	Actual Time	Action	Elapsed Time, min	Amount of Water Permeation, mL
AA-1	8/14/07	11:58 a.m.	Tube filled	0	0
		Leaking; resealed several times.			
	8/15/07	11:20 a.m.	Refilled	0	0
		11:47 a.m.		27	0
		12:00 noon		40	0.1
		12:32 p.m.		72	0.2
		2:56 p.m.	Tube had drained due to leak		
AA-2	8/14/07	11:57 a.m.	Tube filled	0	0
	8/15/07		Refilled and resealed several times		
	8/15/07		Refilled and resealed several times - abandoned		
AA-3	8/14/07	11:56 a.m.	Tube filled; resealed several times		
	8/15/07	11:17 a.m.		0	0
		11:48 a.m.		31	0
		12:01 p.m.		43	0
		12:31 p.m.		74	0
		2:55 p.m.		218	0.1
AA-4	8/14/07	11:57 a.m.	Tube filled; resealed several times		
	8/15/07		Refilled and resealed several times - abandoned		
AA-5	8/14/07	11:54 a.m.	Tube filled, refilled and sealed several times		
	8/15/07		Refilled and resealed several times - abandoned		

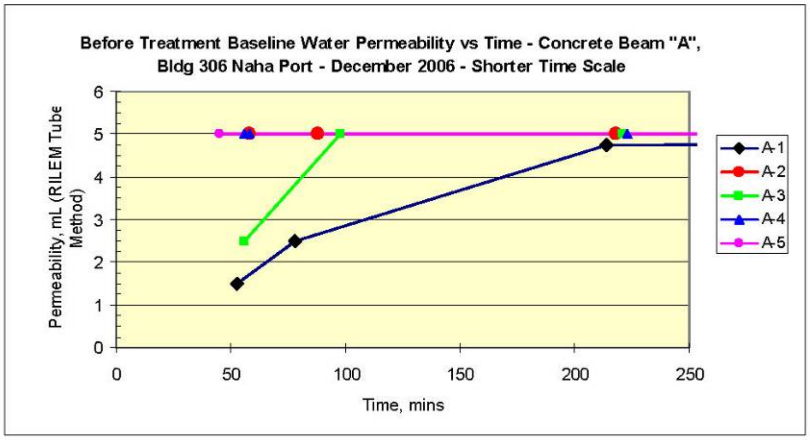
Location	Day/Date	Actual Time	Action	Elapsed Time, min	Amount of Water Permeation, mL
A-1	8/14/07	11:52 a.m.	Tube filled	0	0
	8/14/07	2:28 p.m.		78	5
		Refilled	2:29 p.m.	0	0
			5:28 p.m.	179	4.5
	8/15/07	10:42 a.m.		0	0
		11:57 a.m.		15	1.6
		12:40 p.m.		58	2.5
		2:47 p.m.		185	5
A-2	8/14/07	11:51 a.m.	Tube filled	0	0
	8/14/07	2:26 p.m.		88	5
	8/14/07	2:27 p.m.	Refilled	0	0
		5:27 p.m.		180	5
	8/15/07	11:45 a.m.		0	0
		11:56 a.m.		11	0.4
		12:39 p.m.		54	0.5
		2:49 p.m.		135	0.6
A-3	8/14/07		Tube filled, refilled and repositioned several times due to leaks		
	8/15/07	10:53 a.m.	Refilled	0	0
	8/15/07	11:54a.m.		61	1.7
	8/15/07	12:37 p.m.		104	2.8
	8/15/07	2:51 p.m.		238	5
A-4	8/14/07	11:48 a.m.	Tube filled	0	0
	8/14/07	2:19 p.m.		151	4.5
	8/14/07	2:20 p.m.	Refilled	0	0
		5:21 p.m.		181	2.6
	8/15/07	11:10 a.m.	Refilled	0	0
		11:53 a.m.		43	1.7
		12:36 p.m.		86	2.9
		2:52 p.m.		204	5
A-5	8/14/07	11:44 a.m.	Tube filled	0	0
	8/14/07	2:16 p.m.		152	2.1
	8/14/07	2:17 p.m.	Refilled	0	0
	8/14/07	5:17 p.m.		180	1.7
	8/15/07	11:14 a.m.	Refilled	0	0
	8/15/07	11:52 a.m.		38	0.1
	8/15/07	12:35 p.m.		81	0.3
	8/15/07	2:54 p.m.		220	0.9


Baseline Water Permeability vs Time - Concrete Beam "AA",
Bldg 306 Naha Port - December 2006
Permeability, mL (RILEM Tube Method)
Time, mins
0
200
400
600
800
1000
1200
0
1
2
3
4
5
6
AA-1
AA-2
AA-3
AA-4
AA-5

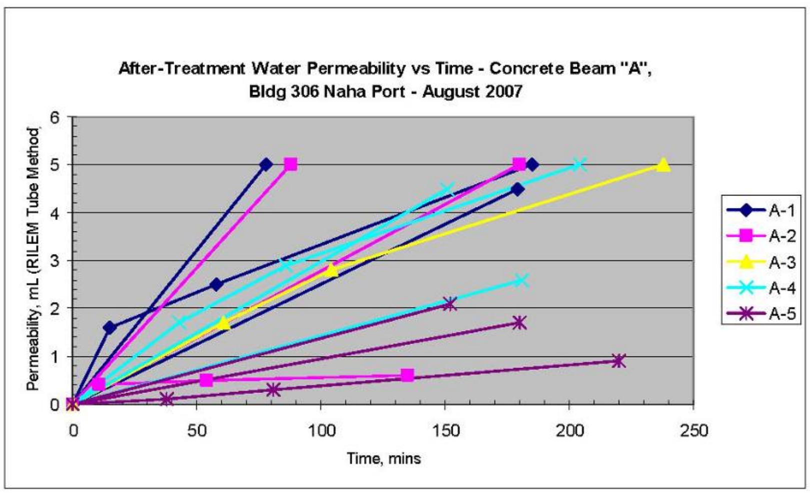

Baseline Water Permeability vs Time - Concrete Beam "A",
Bldg 306 Naha Port - December 2006
Permeability, mL (RILEM Tube Method)
Time, mins
0
200
400
600
800
1000
1200
0
1
2
3
4
5
6
A-1
A-2
A-3
A-4
A-5


Before Treatment Baseline Water Permeability vs Time - Concrete Beam "AA" ; Bldg 306 Naha Port - December 2006 - Shorter Time Scale
Permeability, mL (RILEM Tube Method)
Time, mins
0
1
2
3
4
5
6
0
50
100
150
200
250
AA-1
AA-2
AA-3
AA-4
AA-5


After-Treatment Water Permeability vs Time - Concrete Beam "AA", Bldg 306 Naha Port - August 2007
Permeability, mL (RILEM Tube Method)
Time, mins
0
1
2
3
4
5
6
0
50
100
150
200
250
AA-1
AA-3



Before Treatment Baseline Water Permeability vs Time - Concrete Beam "A", Bldg 306 Naha Port - December 2006 - Shorter Time Scale
Permeability, mL (RILEM Tube Method)
Time, mins
0
1
2
3
4
5
6
0
50
100
150
200
250
A-1
A-2
A-3
A-4
A-5



After-Treatment Water Permeability vs Time - Concrete Beam "A", Bldg 306 Naha Port - August 2007
Permeability, mL (RILEM Tube Method)
Time, mins
0
1
2
3
4
5
6
0
50
100
150
200
250
A-1
A-2
A-3
A-4
A-5

Appendix E: Corrosion Inhibitor Application Process and Product Data Sheets

The corrosion inhibitors are applied to existing concrete structures from water solution and water extended formulations. The liquid inhibitor formulations, inorganic migratory corrosion inhibitor and organic vapor phase corrosion inhibitor, are applied to the concrete surface and allowed to penetrate into the surface pores in the liquid phase. Multiple applications are made followed by water to drive the active ingredients into the concrete micro pore (gel pores) structure. This is referred to as the inoculation phase.

The inorganic migratory corrosion inhibitor active ingredients, silicate ions, migrate into the concrete in the water film along the walls of the cement gel pores. Depending on the structure of the silicate ion clusters they may react with the cement to reduce porosity, increase strength, improve alkalinity and reduce chemical reactivity. A high percentage of the silicate ions in inorganic migratory corrosion inhibitor migrate to the rebar level where they react with the primary oxide film on the rebar to increase resistance to further corrosion.

The organic vapor phase corrosion inhibitor active ingredient is an organic amine salt that migrates through the gel pores in the vapor phase. It will not react with the cement and reaches the rebar level where it both reacts with the primary oxide film to give anodic inhibition and forms a film on the rebar to insulate it from air and water giving cathodic inhibition.

These two processes are called the migration and reaction phases. For rebar at a depth of one inch it normally takes about 30 days for sufficient corrosion inhibitor to reach the rebar level in order to measure a decrease in corrosion rate.

The amount of corrosion inhibitor formulation required and applied will depend on the level of chloride content, pH, rebar depth and concrete porosity.

SURTREAT™

TPS™ II
Material Safety Data Sheet

SECTION I SUPPLIER INFORMATION

Common Name:	SURTREAT-TPS II
Chemical Name:	
Formula:	
Supplier:	SURTREAT Corp. 437 Grant Street, 1210 Frick Building Pittsburgh, PA 15219
Phone:	(412) 281 1202
Emergency Phone:	Chem-Tel 1-800-255-3924 (24 hours)
Date Prepared:	Thursday, October 07, 1999

SECTION II HAZARDOUS INGREDIENT INFORMATION

CFR 29 Part 1910.1000 Table Z-1 (July 1, 1996 issue)

Ingredient	CAS Number	PEL-OSHA (ppm)	TWA-OSHA (mg/m3)	TLV-ACGIH (ppm)	STEL-ACGIH (ppm)

This product contains no hazardous materials.

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point:	212 °F
Specific Gravity:	1.094
Melting Point:	N/A °F
pH:	12
Vapor Pressure (mm Hg):	N/A
Vapor Density (Air=1):	N/A
Evaporation Rate (Butyl Acetate = 1):	N/A
Solubility in Water:	100%
Appearance and Odor:	A clear liquid with a sweet odor.

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash Point:	none °F
Auto-Ignition Temperature:	N/A °F
LEL:	N/A %
UEL:	N/A %
Extinguisher Media:	This material is not expected to burn.
Special Fire Fighting Procedures:	None known.
Unusual Fire and Explosion Hazards:	None known.

SECTION V REACTIVITY DATA

Stability	Stable.
Conditions and Materials to Avoid	Flammable hydrogen gas may be produced on prolonged contact with metals such as aluminum, tin, lead and zinc. Avoid contact with glass and reactive metals.
Hazardous Decomposition or By-Products	Hydrogen gas.
Polymerization	Will not occur.
Conditions to Avoid	None known.

SECTION VI HEALTH HAZARD DATA

Inhalation
Acute — Irritation of eyes, nose and throat, dizziness Chronic No data available.
Eye Contact
Acute — Irritation
Chronic — No data available.
Skin Contact
Acute — Dermatitis
Chronic — No data available.
Ingestion
Acute — Will cause stomach distress, nausea, and vomiting. Large amounts, if retained,lead to symptoms of central nervous system depression.
Chronic — No data available.

Medical Conditions Aggravated By Exposure — Pre-existing eye, skin, and respiratory disorders.
Chemical Listed as Carcinogen or Potential Carcinogen — No
National Toxicology Program — No
I.A.R.C. Monographs : No OSHA : No

ROUTES OF ENTRY/EMERGENCY AND FIRST AID PROCEDURES

Inhalation: Remove to fresh air.
Eyes: Rinse eyes with cool water for 15 minutes and call a physician.
Skin: Remove excess with cloth or paper. Wash thoroughly with soap and water.
Ingestion: Call a physician immediately. Do not induce vomiting. (Vomiting may cause aspiration into lungs resulting in chemical pneumonia.

SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE

Precautions To Be Taken In Handling and Storage: Avoid all ignition sources such as flames and sparks. Do not handle or store at temperatures over 38OC(100OF)
Other Precautions: None

Steps To Be Taken In Case Material Is Released Or Spilled:
Large Spills: Dike and contain for intended use.
Small Spills: Absorb on an inert ingredient such as earth, sand or vermiculite.

Waste Disposal Method: Follow all Local, State, and Federal regulations.

SECTION VIII OTHER REGULATORY INFORMATION

SECTION 313 (With Chemicals Listed): This product contains the following toxic chemical(s) subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and 40 CFR Part 372:

Ingredient	CAS Number	Weight Percent
None	Dry Out	NA

SECTION IX SPECIAL PROTECTION & CONTROL MEASURES

RESPIRATORY PROTECTION: U.S. Bureau of Mines Respirator: self contained breathing device, airline or NIOSH approved respirator.

The specific respirator selected must be based on contamination levels in the work place, must be based on the specific operation, must not exceed the working limits of the respirator, and must be jointly approved by the National Institute of Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH-MSHA).

VENTILATION:	Local Exhaust	Mechanical	Special	other
	XXX			

PROTECTIVE GLOVES: Neoprene
EYE PROTECTION: Goggles
OTHER PROTECTIVE EQUIPMENT: None
WORK/HYGIENE PRACTICES: Keep off of clothing

The information presented herein is based on data considered to be accurate as of the date of preparation of this Material Safety Data Sheet. However, no warranty or representation, expressed or implied, is made as to the accuracy or completeness of the foregoing data and safety information. In addition, no responsibility can be assumed by vendor for any damage or injury resulting from abnormal use, from any failure to adhere to recommended practices, or from any hazards inherent in the nature of the product.

SURTREAT®

TPS™ XII Material Safety Data Sheet

SECTION I SUPPLIER INFORMATION

Common Name:	SURTREAT TPS XII
Chemical Name	Vapor Phase Corrosion Inhibitor Plus Surfactants and Solvents
Supplier:	SURTREAT Corp. 437 Grant Street, 1210 Frick Building Pittsburgh, PA 15219
Phone:	(412) 281 - 1202
Emergency Phone:	Chem-Tel 1-800-255-3924 (24 hours)
Date Prepared:	Tuesday, October 09, 2001

SECTION II HAZARDOUS INGREDIENT INFORMATION

CFR 29 Part 1910.1000 Table Z-1 (July 1, 1996 issue)

Ingredient	CAS Number	PEL-OSHA (ppm)	TWA-OSHA (mg/m3)	TLV-ACGIH (ppm)	STEL-ACGIH (ppm)
Ethylene glycol N-butyl ether	111-76-2	120 mg/m^3		121/mg/m^3	

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point:	212 ^{O}F
Specific Gravity:	1.03
Melting Point:	N/A ^{O}F
pH:	7
Vapor Pressure (mm Hg):	N/A ^{O}F
Vapor Density (Air=1):	N/A
Evaporation Rate (Butyl Acetate = 1):	N/A
Solubility in Water:	100%
Appearance and Odor:	Amber liquid - chemical odor

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash Point:	>212 ^{O}F
Auto-Ignition Temperature:	N/A ^{O}F
LEL:	N/A
UEL:	N/A
Extinguisher Media:	Water, foam, dry, CO_2
Special Fire Fighting Procedures:	Avoid breathing vapors
Unusual Fire and Explosion Hazards:	None

SECTION V REACTIVITY DATA

Stability	Stable
Conditions and Materials to Avoid	Acids, alkalis, strong oxidizing agents
Hazardous Decomposition or By-Products	None known
Polymerization	Will not occur
Conditions to Avoid	None known

SECTION VI HEALTH HAZARD DATA

Inhalation	
Acute	Causes irritation to the respiratory tract.
Chronic	No data available.
Eye Contact	
Acute	May cause irritation and stinging.
Chronic	No data available.
Skin Contact	
Acute	Prolonged exposure may irritate the skin.
Chronic	No data available.
Ingestion	
Acute	May cause headache, dizziness, acidosis, liver and kidney injury.
Chronic	No data available.

Medical Conditions Aggravated By Exposure	Asthma and lung disease, skin diseases.
Chemical Listed as Carcinogen or Potential Carcinogen	No
National Toxicology Program	No
I.A.R.C. Monographs : No OSHA : No	

ROUTES OF ENTRY/EMERGENCY AND FIRST AID PROCEDURES

Inhalation:	Remove victim to fresh air and provide oxygen if breathing is difficult. Get medical attention.
Eyes:	Rinse eyes with cool water for 15 minutes. Get medical attention.
Skin:	Wash off with soap and water. If irritation occurs, get medical attention.
Ingestion:	Drink two glasses of water and induce vomiting. Never give anything to an unconscious person. Get medical attention.

SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE

Precautions To Be Taken In Handling and Storage: Keep product from freezing. If frozen, thaw and agitate before use.
Other Precautions : None

Steps To Be Taken In Case Material Is Released Or Spilled:

Large Spills:	Dike and contain for intended use.
Small Spills:	Absorb on fire retardant treated sawdust
Waste Disposal Method:	Follow all Local, State, and Federal regulations.

SECTION VIII OTHER REGULATORY INFORMATION

SECTION 313 (With Chemicals Listed): This product contains the following toxic chemical(s) subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and 40 CFR Part 372:

Ingredient	CAS Number	Weight Percent
None	N/A	N/A

SECTION IX SPECIAL PROTECTION & CONTROL MEASURES

RESPIRATORY PROTECTION: U.S. Bureau of Mines Respirator; self contained breathing device, airline or NIOSH approved respirator.

The specific respirator selected must be based on contamination levels in the work place, must be based on the specific operation, must not exceed the working limits of the respirator, and must be jointly approved by the National Institute of Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH-MSHA).

VENTILATION:	Local	Exhaust	Mechanical	Special	Other
	XXX				

Protective Gloves:	Rubber
Eye Protection:	Goggles
Other Protective Clothing or Equipment:	None
Work/Hygiene Practices :	Keep off of clothing

The information presented herein is based on data considered to be accurate as of the date of preparation of this Material Safety Data Sheet. However, no warranty or representation, expressed or implied, is made as to the accuracy or completeness of the foregoing data and safety information. In addition, no responsibility can be assumed by vendor for any damage or injury resulting from abnormal use, from any failure to adhere to recommended practices, or from any hazards inherent in the nature of the product.

MATERIAL SAFETY DATA SHEET

SECTION I SUPPLIER INFORMATION

Common Name:	TPS XVII
Chemical Name:	
Formula:	
Supplied by:	Surtreat International 1360 N Wood Dale Road, Suite A Wood Dale, Illinois 60191
Supplier Phone:	1 877-SURTREAT
Manufactured by:	Shore Corporation 2917 Spruce Way Pittsburgh, PA 15201
Manufacturer Phone:	(412) 471-3330
Emergency Phone:	Chem-Tel 1-800-255-3924 (24 hours)
Date Prepared	December 19, 2006
Edit Date	December 19, 2006

SECTION II HAZARDOUS INGREDIENT INFORMATION

CFR 29 Part 1910.1000 Table Z-1 (July 1, 2001 issue)

Ingredient	CAS Number	PEL-OSHA (ppm)	TWA-OSHA (mg/m^3)	TLV-ACGIH (ppm)	STEL-ACGIH (ppm)
Acetic Acid	64-19-7	10	25	10	15
Tetraethyl Silicate	78-10-4	100	850	10	
Ethyl Alcohol	64-17-5	1000	1880	1000	
Methyl Alcohol	67-56-1	200	262	200	250

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point:	NA °F
Specific Gravity:	0.96
Melting Point:	N/A °F
pH:	5.0 – 6.0
Vapor Pressure (mm Hg):	N/A
Vapor Density (Air=1):	N/A
Evaporation Rate (Butyl Acetate =1):	N/A
Solubility in Water:	100% Miscible
Appearance and Odor:	A clear yellowish liquid with a mild odor.

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash Point:	77 °F
Auto-Ignition Temperature:	590 °F
LEL:	5.5 %
UEL:	44 %
Extinguisher Media:	Flammable liquid, use CO_2, Dry Chemical, Foam Extinguisher or water mist. Do not use a direct water stream.
Special Fire Fighting Procedures:	Fire-fighter should wear self-contained breathing apparatus and full protective

	clothing. Use water spray to cool nearby containers and structures exposed to fire.
Unusual Fire and Explosion Hazards:	Reaction with water may cause a decrease in the flash point due to formation of volatile organic compounds (VOCs). As a result of hydrolysis flammable vapors may accumulate in the container headspace.

SECTION V REACTIVITY DATA

Stability	Stable
Conditions and Materials to Avoid	Reacts slowly with water. Reaction causes the formation of methanol, ethanol. There is also a lowering of the flashpoint.
Hazardous Decomposition or By-Products	Under effect of humidity, water, ethanol, methanol. Measurements have shown the formation of formaldehyde at temperatures about 302°F through oxidation.
Polymerization	None
Conditions to Avoid	None known

SECTION VI HEALTH HAZARD DATA

Inhalation

Acute — Prolonged or repeated exposure or breathing very high concentrations may cause headaches, nausea, vomiting, dizziness, visual disturbances, giddiness, intoxication, sleepiness, unconsciousness and death. Initial symptoms of inhalation may only be mild intoxication but may become more severe after 12-18 hours. Toxic effects are exerted on the central nervous system, especially the optic nerve.

Chronic

Eye Contact

Acute — Causes eye irritation. May cause permanent eye damage

Chronic

Skin Contact

Acute — Brief contact may dry the skin. Prolonged or repeated contact may irritate the skin, causing dermatitis.

Chronic

Ingestion

Acute — This product releases methanol upon hydrolysis. According to literature, swallowing 100-250 mls of methanol can be fatal. Swallowing lesser quantities can cause blindness, dizziness, headaches or nausea. Absorption of methanol is rapid but excretion is slow, resulting in delayed effects or compounding effects of repeated exposure. Initial symptoms may only be mild intoxication but these may become more severe 12-18 hours later. Toxic effects are exerted on the central nervous system, especially the optic nerve.

Chronic — Prolonged or repeated exposure may result in central nervous system damage, blindness, damage to pancreas or death.

Medical Conditions Aggravated By Exposure	Unknown
Chemical Listed as Carcinogen or Potential Carcinogen	No
National Toxicology Program	No

I.A.R.C. Monographs: No OSHA: No

ROUTES OF ENTRY/EMERGENCY AND FIRST AID PROCEDURES

Inhalation — Remove to fresh air. Give artificial respiration if not breathing. If breathing id difficult, administer oxygen. Get immediate medical attention.

Eyes: — Rinse eyes with cool water for 15 Minutes, lifting the upper and lower eyelids occasionally. If stinging persists, get medical attention.

Skin: — Wipe away excess material. Use a waterless hand cleaner to remove as much of material as possible. Wash with soap and water. Remove contaminated clothing and shoes; wash before reuse. Get medical attention if irritation persists

after washing.

Ingestion: If conscious, immediately induce vomiting by giving 2 glasses of water and sticking a finger down the throat or using syrup of Ipecac. Give fluids until the vomitus is clear. Get immediate medical attention. Consider poisoning of methanol. Do not give anything to an unconscious or convulsing person.

SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE

Precautions To Be Taken In Handling and Storage: Keep away from heat, sparks, and flames. Store in a cool, dry, well-ventilated place away from incompatible materials. Vent container frequently, and more often in warm weather, to relieve pressure. Electrically ground all equipment when handling this product and use only non-sparking tools. Keep container tightly closed when not in use. Do not use pressure to empty container. Wash thoroughly after handling. Do not get in eyes, on skin, or clothing.

Other Precautions : Do not cut, grind, weld, or drill on or near this container. Containers, even those that have been emptied, will retain product residue and vapors. Always obey hazard warnings and handle empty containers as if they were full.

Steps To Be Taken In Case Material Is Released Or Spilled: Wear protective equipment including rubber boots, rubber gloves, rubber apron, and a self-contained breathing apparatus in the pressure demand mode or a supplied-air respirator. In any event, always wear eye protection. Extinguish all ignition sources and ensure that all handling equipment is electrically grounded.
Large Spills: Contain by diking with soil or other non-combustible absorbent materials and then pump into DOT-approved waste containers; or absorb with non-combustible sorbent materials, place residue in DOT-approved waste containers. Keep out of sewers, storm drains, surface waters and soil.
Small Spills: Mop or wipe up and dispose of in DOT-approved waste containers.

Waste Disposal Method: Follow all Local, State, and Federal Regulations in your area.

SECTION VIII OTHER REGULATORY INFORMATION

SECTION 313 (With Chemicals Listed): This product contains the following toxic chemical(s) subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and 40 CFR Part 372:

Ingredient	CAS Number	Weight Percent
Methyl Alcohol	67-56-1	<1.0

SECTION IX SPECIAL PROTECTION & CONTROL MEASURES

RESPIRATORY PROTECTION: U.S. Bureau of Mines Respirator; self-contained breathing device, airline or NIOSH approved respirator.

The specific respirator selected must be based on contamination levels in the work place, must be based on the specific operation, must not exceed the working limits of the respirator, and must be jointly approved by the National Institute of Occupational Safety and Health and the Mine Safety and Health Administration (NIOSH-MSHA).

VENTILATION:	Local Exhaust	Mechanical	Special	Other
	xxx			

Protective Gloves: Rubber

Eye Protection: Goggles

Other Protective Clothing or Equipment: Were impervious clothing and boots.

Work/Hygiene Practices : Keep off of clothing

SECTION X DOT SHIPPING INFORMATION

DOT Shipping Name: Flammable liquid, n.o.s. (contains trimethoxy (2,4,4-trimethylpentyl) silane), PG III, 3, UN - 1993
Label Requirements: FLAMMABLE

DOT Hazardous Substance	CAS Number	Reportable Quantity (RQ)
Acetic Acid	64-19-7	5000 lbs.
Ethyl Alcohol	64-17-5	5000lbs.

The information presented herein is based on data considered to be accurate as of the date of preparation of this Material Safety Data Sheet. However, no warranty or representation, expressed or implied, is made as to the accuracy or completeness of the foregoing data and safety information. In addition, no responsibility can be assumed by vendor for any damage or injury resulting from abnormal use, from any failure to adhere to recommended practices, or from any hazards inherent in the nature of the product.

Appendix F: Technical Information on Galvapulse and GWT Metrics Technologies

GalvaPulse

Purpose

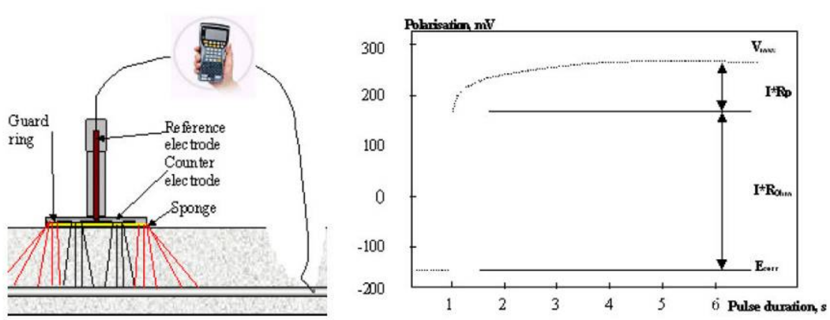
Reliably to measure the reinforcement corrosion for

- Service life estimation
- Evaluating the efficiency of corrosion arresting measures such as application of inhibitors, membranes or electrochemical removal of chlorides
- Condition surveys of suspect reinforced structures, especially structures in wet environment where the classic potential mapping may provide misleading and/or insufficient information
- Monitoring RC structures for corrosion activity
- Testing the corrosion activity in repaired areas

Principle

The reinforcement corrosion is evaluated by the corrosion rate stating how much steel is being dissolved in µm/year (10^-3mm/year). In addition, half-cell potentials and the electrical resistance of the cover layer is measured.

The principle of the corrosion rate measurement is the following.



An anodic current pulse "I" is imposed on the reinforcement from a counter electrode placed on the concrete surface. A guard ring confines the current to an area "A" of the reinforcement below the central counter electrode.

The applied current is usually in the range of 5 to 400 µA and the typical pulse duration is 5-10 seconds. The reinforcement is polarized in the anodic direction compared to its free corrosion potential. With a Ag/AgCl reference electrode the resulting change of the electrochemical potential of the reinforcement is recorded as a function of time. A typical potential response for a corroding reinforcement is shown in the right figure above.

When the constant current "I" is applied to the system, an ohm´ic potential drop "I*ROhm" occur as well as a polarization of the reinforcement "I*Rp". The polarization resistance of the reinforcement "Rp" is calculated. By means of the Stern Geary equation for active corrosion Icorr =26/Rp and Faraday's law

of electrochemical equivalence, the corrosion rate is estimated as:

$$\text{Corrosion Rate} = 11.6 \cdot I_{corr}/A$$

with the corrosion rate given in µm/year (0.001mm/year). "Icorr" is the corrosion current in µA and "A" the confined area of the reinforcement in cm^2 below the central counter electrode. The factor 11.6 is for black steel.

Precision and variation
The half-cell potentials measured with the Ag/AgCl electrode is within ± 5 mV from a calibrated one. The electrical resistance variation is less than ± 5%.

The precision of the corrosion can only be evaluated by comparison to actual weight loss measurement of the reinforcement subjected to long term corrosion conditions.

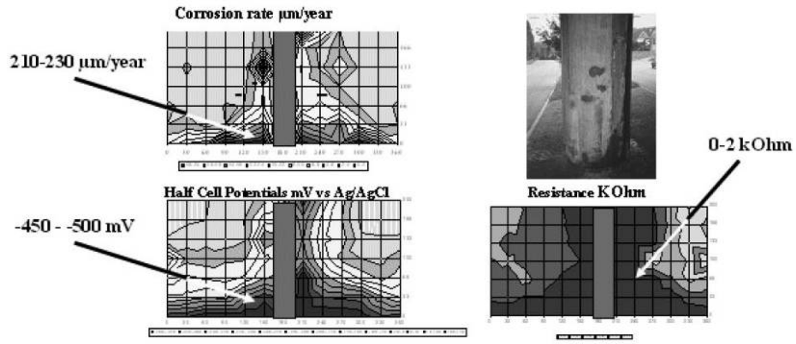
One such laboratory investigation produced the following comparison between corrosion rates calculated from weight loss measurements and the GalvaPulse, *c.f. Baessler,R. & Burkert,A.: "Laboratory Testing of Portable Equipment", Brite/Euram Project Integrated Monitoring System for Durability Assessment of Concrete Structures, BAM (Federal Institute for Materials and Testing), Berlin, Germany, 2001*

	Weight Loss	***GalvaPulse***
Reinforcement	Corrosion rate (µm/year)	Corrosion rate (µm/year)
A	53	36
B	56	29
A+B connected	55	61

The findings support the general conclusion that the GalvaPulse in anodic areas is accurate well within a factor of two for estimating the corrosion rate. In addition should be taken into account the practical uncertainties when testing on site, e.g. the actual area of the reinforcement being polarized and the variation over time in corrosion rates related to temperature and moisture variations.

In passive reinforcement areas (corrosion rates < 1 µm/year) the GalvaPulse will overestimate the corrosion rate by a factor of 3-4 times. Such areas are, however, not interesting in terms of corrosion.

In another study, a long term field study, 30 year old bridge columns subjected to deicing salts were examined regularly over a 20 years period since the corrosion started out. The chloride levels in the concrete of the bridge were high as well as the humidity. In April 2001, where the last measurements were performed, the temperature was 15°C. The test results are illustrated below.



The fairly constant corrosion rates as stated measured over the past 20 years corresponds to a cross section loss of the reinforcement of 20 years times 0.22 mm per year = 4.4 mm.

Opening at a couple of locations at the bottom of the columns revealed an approximate 4 mm cross section loss of the reinforcement.

The GalvaPulse features

- Reliable evaluation of the reinforcement corrosion in anaerobic concrete environment
- Lightweight, handheld equipment, easy to operate
- Two operation modes, one for speedy measurement using only half-cell potentials and electrical resistance (1-2 seconds per test), and another for corrosion rate, half-cell potentials and electrical resistance (5-10 seconds per test). The first mode is normally used to identify the anodic and the cathodic areas, while the last one is used in anodic areas, where the corrosion rate is a decisive parameter to be measured
- Testing on rough or curved surfaces
- Storage capacity of up to 20,000 records in the handheld computer
- Easy to use Windows based software for presentation of the test results in 2D or 3D color graphics
- Portable system including calibration unit and a check block with a stainless steel and a corroding black steel bar embedded

Testing examples

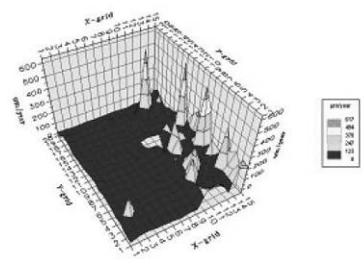
GalvaPulse corrosion rate measurement at a leaking joint

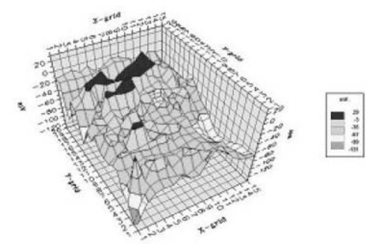
Highway bridge column being tested for corrosion rate with the GalvaPulse

Corrosion activity being evaluated on a bridge wall with the GalvaPulse

GalvaPulse testing in progress for corrosion activity of a heavily corroded column

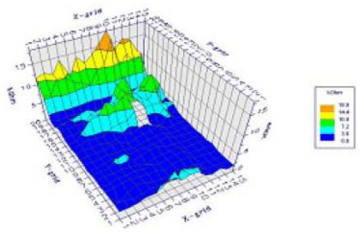
Examples of the GalvaPulse Data Viewing Graphics





Following testing the handheld computer is connected to a

PC with installed Windows based GalvaPulse Viewing and Reporting software. The records are transferred and color plotting takes place in 2D or 3D graphics as illustrated of the corrosion rates (above), the half-cell potentials (above right) and the electrical resistance (right), for documentation and reporting.



The GalvaPulse and ordering numbers

Item	***Order*** #
Handheld computer with installed GalvaPulse software and pulse generator	GP-5010
Calibration unit for pulse generator	GP-5020
Measuring cell with 3 meter cable	GP-5030
Sponge for measuring cell	GP-5040
Reinforcement locator	GP-5050
Reinforcement conductivity meter	GP-5060
Cable for data transfer to PC	GP-5070
Measuring cable	GP-5080
Two adjustable reinforcement clamps	GP-5090
Two reinforcement adaptors	GP-5100
12 mm and 18 mm drill bits	GP-5110
10 mm Allen key	GP-5120
Sponge for grinding of electrode rings	GP-5130
Hammer and chisel	GP-5140
Measuring tape and chalk	GP-5150
CD-ROM, GalvaPulse Data Viewing and reporting software	GP-5160
Manual	GP-5170
Attaché case	GP-5180

Supplied separately with the GP-5000 Kit:

Item	***Order*** #
Cable drum with 15 meters of cable	GP-5190
Check block with embedded a corroding rebar and a stainless steel rebar	GP-5200

GP-5000 GalvaPulse System

Optionally:
Angle Electrode,
GP-5210

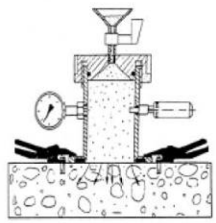
GWT

Purpose

The GWT (Germann´s Water permeation Test) is used for on-site evaluation of

- The skin-concrete of the finished structure
- The water permeation of concrete, mortar, bricks and joints
- The water tightness of construction joints
- Effectiveness of water proofing membranes

Principle



Water is pressurized to the surface of a material and the water permeation is measured.
A pressure chamber containing a watertight gasket is secured tightly to the surface by two anchored clamping pliers or by means of a suction plate. The gasket may optionally be glued to the surface.

The chamber is filled with water and the valves closed. The top lid of the chamber is turned until a desired water pressure is achieved.
The pressure selected is maintained by means of a micrometer gauge pressing a piston into the chamber, substituting the water penetrating into the material.

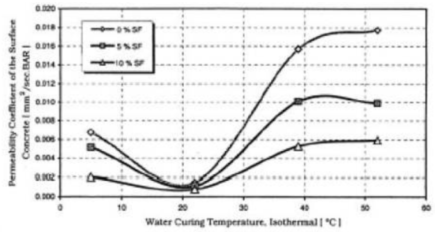
The travel of the piston over time is used for characterizing the permeation of the surface tested.

Precision and variation

No precision statement has been published on the GWT. The variation on the estimate is within ±10 %.

Testing examples

*High performance concrete being tested with the GWT. The four cone holes shown adjacent are from CAPO-TEST. At a pressure of 1 BAR (right photo) water was observed to penetrate through surface cracks. After grinding 1.5 mm deep the test was repeated (left photo), and the pressure increased to 5 BAR. No penetration through cracks was observed. A water flux of 1.3 * 10^-5mm/s was measured.*



Water permeability of concrete measured with the GWT, for different water curing temperatures and silica fume (SF) contents. The w/c-ratio of the concrete was 0.42 and the compressive strength 40 MPa.

The GWT used for testing the water tightness of a brick wall. During raining and for a normal wind pressure water had penetrated the wall. The problem showed to be the related to the bricks, not to the mortar joints. The bricks had been burned at a higher temperature than normal to produce a required color, but at the same time caused the bricks to become highly permeable.

The GWT and ordering numbers

GWT-4000 Kit

Item	*Order #*
Pressure chamber unit with 0-1.5 BAR gauge installed	GWT-4010
Wrench for pressure lid	GWT-4020
Extra 0-6.0 BAR gauge	GWT-4030
Water filling cup w. L-joint	GWT-4040
Adjustable clamping pliers	GWT-4050
Set of anchoring tools	GWT-4060
Wrenches, 14 & 17 mm	GWT-4070
Sealant tape	GWT-4080
Bottles with boiled water, 3	GWT-4090
Gaskets, 10 mm high, 4	GWT-4100
Gaskets, 15 mm high, 4	GWT-4110
Manual	GWT-4120
Attaché case	GWT-4130

Appendix G: Suggested Implementation Guidance

Proposed Draft for UNIFIED FACILITIES GUIDE SPECIFICATION

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Division Concrete

PENETRATING CORROSION INHIBITOR SYSTEM FOR STEEL REINFORCED CONCRETE

02/08

PART 1 GENERAL

a. Rebar Corrosion Rate
b. Concrete Water Penetration Rate
c. Concrete Strength

PART 2 PRODUCTS

2.1 Penetrating Vapor Phase Corrosion Inhibitors
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3.1 Application of Vapor Phase Corrosion Inhibitor
3.2 Application of Ionic Phase Corrosion Inhibitor
3.3 Application of Vapor Phase and Ionic Phase Corrosion Inhibitors in Combination
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a. Water Repellents

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5.2.2.1 UNIFIED FACILITIES GUIDE SPECIFICATION

Section Concrete

PENETRATING CORROSION INHIBITOR SYSTEM FOR STEEL REINFORCED CONCRETE

02/08

This guide specification covers the requirements for the application of corrosion inhibitors to the surface of in-place reinforced concrete structures. The inhibitors migrate in either the vapor or ionic phases to the rebar level where they inhibit steel corrosion, and are designed to reduce concrete porosity and increase concrete strength.

The specification may be modified to meet specific project conditions to the extent that such modifications do not reduce corrosion inhibitor performance.

Prior to starting work on a project this entire specification must be read and a project specific work plan prepared following all elements of the

guide. Any deviations must meet the requirements of acceptable variation. Application and testing equipment should be identified and acquired. Pre-application testing must be conducted as part of the work plan preparation so that the required amount of corrosion inhibitor and the application procedure can be identified based on the rebar corrosion rate, and the concrete chloride content, pH and porosity.

PART 1 GENERAL

1.1 References

The publications and reports listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation.

AASHTO T-260 Sampling and Testing For Chloride Ion In Concrete And Concrete Raw Materials

ASTM C900-99 Standard Test Method for Pull-Out Strength of Hardened Concrete

ASTM C805 Schmidt Hammer Standard Test Method for Rebound Number of Hardened Concrete

ASTM C-876 Standard Test Method for Half-Cell Potential of Uncoated Reinforcing Steel in Concrete

Gulvapulse Corrosion rate Data Detection Reference Equipment Guide and Specifications from Germann Instruments, Evanston, Illinois

GWT Water Permeability Reference Equipment Guide and Specifications from Germann Instruments, Evanston, Illinois.

pH Rainbow Indicator pH/Carbonation Profile Indicator Reference Equipment Guide and Specifications from Germann Instruments, Evanston, Illinois

1.2 Submittals

The following submittals should be requested from contractors and product suppliers to confirm competence and experience to perform project objectives.

- Product Data Sheets
- Test Reports
  -Corrosion Inhibitor Performance
  -Concrete Porosity Reduction Performance
  -Concrete Strength Increase performance

- Certificates
  -Manufacturers Qualifications
  -Applicators Qualifications
  -Evidence of Acceptable Variation
  -Warranty

- Manufacturers Instructions
  -Application Instructions
  -Material Safety Data Sheets

1.3 Quality Assurance

1.3.1 Qualifications

The contractor retained to apply the penetrating corrosion inhibitors must document prior experience on projects where both vapor and ionic phase corrosion inhibitors were applied to vertical and horizontal concrete surfaces and before and after corrosion rate testing was performed and documented to verify that the application was successful in penetrating sufficient inhibitor to the rebar level to reduce the corrosion rate by at least a factor of two.

If the contractor does not have this experience over at least a 5-year period they must retain the services of a consultant who has the required experience to supervise on site the pre-application testing, the application of the corrosion inhibitors and the post application testing to verify performance.

1.3.2 Performance Requirements

Corrosion inhibitor performance must be verified by before and after application corrosion rate measurements. This also includes other performance objectives such as porosity reduction and concrete strength increase if these are made part of the project. In general the corrosion rate should be reduced by a factor of 2 times and porosity by 80% of the original rate and concrete strength increased by 500 psi based on relative compressive strength.

1.3.3 Evidence Of Acceptable Variation

If there are any variations from this specification documentation must be presented to verify that the variation will not result in a less than acceptable result.

1.4 Regulatory Requirements

1.4.1 Environmental Protection

Product MSDS must be acquired from product supplier and administrative steps taken to be in compliance with all requirements as related to the specific project conditions. If there are any exceptions to be made they must be approved by the product supplier.

1.5 Delivery And Storage

Corrosion inhibitor products must be delivered in sealed and properly labeled containers. Products must be stored and handled in accordance with manufacturer's instructions. If no instructions are received the contractor must require submittal before payment is made.

1.6 Safety Methods

Safety methods employed on project must be in compliance with all OSHA standards for personal protection and include the required record keeping and training.

1.7 Environmental Conditions

1.7.1 Weather and Substrate Condition

If a project is being performed outdoors the present and forecasted weather conditions must be considered. Spray application is not advised in windy conditions. Brush or roller applications methods should be used. Do not apply if rain is expected during the application process. Since all of the corrosion inhibitor must penetrate during application there is no concern about rain occurring a few hours after application is completed.

Substrate temperature must be considered since a high rate of solvent carrier evaporation can lead to excess inhibitor remaining on the concrete surface. Surface temperatures below 35F and above 100F should be avoided in order to have optimum conditions for inhibitor penetration into the concrete surface.

1.8 Equipment, Tools And Machines

A spray bar attached to a mobile tank can be used for application to large flat surfaces. Power fed rollers and spray systems can be used for vertical and overhead surfaces. For small areas garden type spray tanks can be used.

It is useful to have brooms, squeegees and brushes available to control the flow and position of liquid corrosion inhibitors on the concrete surface.

Both types of corrosion inhibitors can be applied using the same equipment.

Devices that allow the use of pressure to force the inhibitor products into the concrete surface are recommended for use on vertical and overhead surfaces. The use of pressure injection will enable application of the desired amount of inhibitor in one pass while multiple applications cycles will be needed if a simple spray system is used.

1.9 Sequencing And Scheduling

1.9.1 Surface Preparation

The first step after setting up at the project site is to prepare the concrete surface for repair and corrosion inhibitor application. All coatings and other substances that could interfere with inhibitor penetration must be removed. Removal methods should be selected that are best suited for the material and work location. Delaminated concrete should be removed and the damaged areas and cracks prepared for repair and sealing in accordance with specified procedures.

1.9.2 Surface Repair

Damaged concrete areas and cracks should be repaired following procedures as specified by the Project Engineer.

1.9.3 Pre-Application Testing

a. Rebar Corrosion Rate

The base line rebar corrosion rate is measured in a manner that will allow for measurements to be made after inhibitor application under the same conditions and at the same locations to determine the extent of corrosion rate reduction.

There are a number of methods for measuring corrosion rate and/or half-cell potential. The sources of technical information for these methods and standards are in Section 1.1 References. The following procedure is recommended for rapidly making multiple measurements that can be used to document the change in rebar corrosion rate.

During the surface preparation stage when rebar may be exposed prior to performing repair work a wire should be attached to the rebar and brought out from the repair surface for use in grounding a corrosion rate measuring instrument. If no exposed rebar is available the concrete surface must be opened to extent necessary to locate a rebar section that is electrically connected to the rebar mat and to which a ground wire can be attached.

A corrosion rate-measuring device should be obtained such as the Galvapulse instrument (Section 1.1) that can measure rebar corrosion rate by polarization resistance along with half-cell potential. Rebar position is located using a rebar finder and a test matrix is marked out on the concrete surface next to a ground wire. For each treated area it is recommended that at least 25 measurement points over a rebar section be made. At least two separate areas should be selected for a measurement matrix. The specific conditions of concrete moisture content and temperature should be recorded for future reference. Corrosion rate is reported in micro amps per square centimeters of rebar surface in the test (uA/cm2) or micrometers of steel loss per year (uM/yr). Half-cell potential can also be measured, but only corrosion rate is used to measure performance.

b. Cement Chloride Content

A sample of the sand /cement phase (no coarse aggregate) of the concrete is taken at the first rebar level. Sample acquisition and chloride ion measurement should be performed in accordance with ASHTO and ASTM methods (see Section 1.1). Chloride content is considered to determine the amount of corrosion inhibitor that must be applied to the concrete. Chloride content typically ranges from 50 to 1000ppm. Prior experience has shown that at total chloride levels above 3000ppm that the probability of a corrosion inhibitor giving a significant reduction in corrosion rate is low. It is

recommended that at high chloride levels a pre-project test application be made to ensure performance.

c. Cement pH

The pH of fresh concrete (cement mix, no additives) is between 12 to 13. As concrete ages the pH drops due to carbonation. At a pH less than 11.5 the cement alkalinity no longer inhibits rebar corrosion in the presence of air and water.

pH is measured from the concrete surface to the first rebar level. It is recommended that a small core be taken and coated with a mixed pH indictor dye (see Section 1.1).

d. Water Penetration Rate

The water penetration rate is useful information, as it relates to concrete porosity and the ease with which the corrosion inhibitors will penetrate the concrete surface. Also it will be useful to determine the extent to which the ionic phase corrosion inhibitor reduced the cement porosity.

Water penetration rate can be measured at atmospheric (Rilem Tube method) and elevated pressure (GWT (Section 1.1) instrument). Details on the water penetration measurement methods and devices are in Section 1.1. Penetration rate measurements should be made in at least two areas.

e. Concrete Strength

Concrete strength improvement is a secondary benefit that can be observed by using an ionic phase type of corrosion inhibitor. Since the concrete strength increase occurs in the first 2 inches of concrete surface it is recommended that the Capo Pull Out method (Section 1.1) be used. Measurements should be made in at least 2 areas.

1.9.4 Pre-Application Planning

When the pre-application testing is completed the results are used to prepare a specific corrosion inhibitor application plan that includes product selection, application rate and method. When preparing the plan the following factors need to consider.

- Average corrosion rate based on all data points

- The cement chloride ion concentration
- Cement pH
- Concrete porosity
- Rebar depth
- Concrete structure configuration

The final application plan should be presented and reviewed with the customer or project engineer for comments and approval.

1.9.5 Corrosion Inhibitor Application

The selected corrosion inhibitors are applied in accordance with the application plan. If both the vapor and ionic phase inhibitors are applied the vapor phase is applied first. At least 1 day should be allowed for the formulation solvent to evaporate before applying the ionic phase inhibitor.

The quantity of inhibitor delivered to the concrete surface should be monitored and recorded. The loss of inhibitor due to running or dripping from the surface should be avoided. If there is any loss, an appropriate amount of additional inhibitor should be added.

On completion of inhibitor application the concrete surface should be inspected to make sure that all inhibitor has penetrated the concrete surface.

In some instances the ionic phase inhibitor will purge contaminants from the concrete such as oil and salt. If these appear on the concrete surface they should be removed to the extent possible.

1.9.6 Post Application Testing

A period of at least 60 days should be allowed after completion of corrosion inhibitor application before performing tests. This will allow time for the inhibitors active ingredients to migrate and react at the rebar level and for the ingredients in the ionic inhibitor to react with the cement to reduce porosity and increase strength.

a. Rebar Corrosion Rate

   Using the same instrument and measurement matrix make corrosion rate measurements. The corrosion rate data collected before and after application are compared to determine the extent of corrosion rate reduction. This can be done by calculating the

average of all rates and comparing the difference in terms of percent or degree of reduction. Based on prior comparative test data the change should be at least 200% of a factor of 2 times less corrosion.

b. Water Penetration Rate

Repeat the same water penetration rate measurement on the same spot and record the difference in the before and after application rates. It is anticipated that the after application rate should be 80% less if the proper ionic inhibitor was applied.

c. Concrete Strength

The same strength test should be repeated on the concrete surface next to the spot where the pre-application test was run. The difference in relative strength is reported in lbs/ft^2 and should be at least 500psi if the proper ionic inhibitor was applied.

PART 2 PRODUCTS

There are two types of penetrating corrosion inhibitors that have been verified for inhibiting corrosion of reinforced concrete rebar. They differ by the nature of their chemical structure (organic and inorganic) their mode of migration (vapor and ionic phase) and mode of corrosion inhibition (film forming and chemical combination). Both penetrate and migrate through the cement micro pores (gel pores).

These inhibitors can be used alone or in combination. If used in combination the vapor phase one is applied first. They can also be used in combination with cathodic protection coatings, water repellents and barrier coatings to further increase corrosion protection.

2.1 Penetrating Vapor Phase Corrosion Inhibitor

Vapor phase inhibitors migrate in the gas phase through the cement gel pores and form a corrosion inhibiting film on the rebar surface. They are typically organic amine salts or amino alcohols dissolved in a water based formulation.

2.2 Penetrating Ionic Phase Corrosion Inhibitors

Ionic phase inhibitors are inorganic compounds that migrate in the ionic phase along the walls of the cement gel pores and then react with the primary oxide film on the rebar surface to form a chemical combination that significantly increases the stability of the primary oxide or passivating film. They are primarily composed of compounds containing silicate and nitrite ions.

Two secondary benefits can be derived from the use of penetrating ionic phase corrosion inhibitors. They are concrete porosity reduction and strength increase. While these are secondary to corrosion control these two properties can be specified as an additional performance benefit.

PART 3 EXECUTION

3.1 Application Of Vapor Phase Corrosion Inhibitors

The selected vapor phase corrosion inhibitor should be applied at the prescribed application rate and by the selected method. Special application instructions should be followed as stated in the manufacturer's technical data sheet as well as the instructions cited in this guide.

In all cases it is important to verify that the prescribed amount of inhibitor has penetrated the concrete surface. Prior experience has taught that multiple applications are usually required.

3.2 Application of Ionic Phase Corrosion Inhibitor

The selected ionic phase corrosion inhibitor should be applied at the prescribed application rate by the selected application method. Special instructions should be followed as stated in the manufacturers technical data sheet as well as the instructions cited in this guide.

In all cases it is important to verify that the prescribed amount of inhibitor has penetrated the concrete surface. Prior experience has taught that multiple applications are usually required.

It has been observed that the ionic phase inhibitors have the capacity to purge contaminants from the concrete. These should not be confused with inhibitor left on the surface and can be removed if necessary by any appropriate method.

3.3 Application Of Vapor and Ionic Phase Corrosion Inhibitors In Combination

If both the vapor phase and ionic phase inhibitors are used together the vapor phase inhibitor is applied first. At least 1 (one) day is allowed to pass before the ionic phase inhibitor is applied to allow time for the formulation solvents to evaporate.

The same application instruction should be followed as given in the guide for the individual inhibitors. It is recommended that both inhibitors be used; since the combination will yield a higher and longer lasting level of rebar corrosion inhibition.

3.4 Application Of Surface Coatings

The concrete surface must be inspected and cleaned if necessary to make sure that there are no residues on the surface if a surface coating that produces a bonded film is applied on top of the corrosion inhibitors. The surface can be cleaned of residues by the use of pressure water washing.

3.4.1 Protective And Finish Coatings

a. Water Repellents

   Silane and siloxane type of water repellents can be applied on top of both vapor and ionic phase corrosion inhibitors. This is done to furnish another degree of corrosion protection by reducing the concrete moisture content. Application is made following the manufacturer's instructions.

b. Protective And Decorative Coatings

   Paint type film forming and cement topcoats can be applied on top of both vapor and ionic phase corrosion inhibitors. It is necessary to inspect and prepare the concrete surface to insure that there are no residues on the surface.

   The coatings are applied in accordance with the manufacturer's instructions.

Appendix H: Contractor Planning and Safety Documents

SITE SPECIFIC HEALTH, & SAFETY PLAN
DRAFT REV. 1 / SEPTEMBER 2006

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1.0 INTRODUCTION

This document describes the health and safety guidelines developed for Task Order W9132T-SUR-001 issued by Mandaree Enterprise Corporation (MEC), Warner Robbins GA for installation of corrosion protection inhibitor for rebar in concrete in Okinawa Japan. to protect on-site personnel, visitors, and the public from physical harm and exposure to hazardous materials or wastes. The procedures and guidelines contained herein were based upon the best available information at the time of the plan's preparation. Specific requirements will be revised when new information is received or conditions change. A written amendment will document all changes made to the plan. Any amendments to this plan will be documented using the form in Attachment A and included in Attachment A. Where appropriate, specific OSHA and Okinawa standards or other guidance will be cited and applied. Surtreat Holding LLC will also establish and maintain the minimum kinds and amounts of insurance during performance of this Agreement as specified by FAR 28.307-2, Liability, and contemplated by FAR 52.228-5, Insurance – Work on a Government Installation, and/or 52.228-7, Insurance – Liability to third Persons. Proof of insurance will be supplied upon request of MEC

All work practices and procedures implemented on-site must be designed to minimize worker contact with hazardous materials and to reduce the possibility of physical injury. All work will be performed in accordance with applicable 29 CFR 1910 & 1926 Health & Safety Regulations.

The purpose for this Site-specific Health & Safety Plan (HASP) is to set forth, in an orderly and logical fashion, appropriate safety procedures to be followed during on-site remedial activities at the Okinawa Japan site.

SURTREAT's mission is to provide cost effective and timely solutions, but to do so while maintaining the industry benchmark for health and safety on each project. With this as our goal, the following safety and health program will be implemented to address concrete sealing activities conducted at the Okinawa Facility.

During concrete restoration and related activities, SURTREAT will work in conjunction with MEC, Construction Engineering Research Laboratory (CERL), the local Okinawa Japan representatives and will maintain an on-going safety process and therefore will continually instruct, promote and prepare all associates for their positions. It is through this work process that SURTREAT will achieve a safe work environment.

"Safety is a state of mind" that must be nurtured and reinforced every day. SURTREAT's education and training of associates provides the insight to safety protocol and the understanding of specific requirements. As part of our safety culture, a project orientation will be completed along with daily safety meetings held at the start of each workday to ensure that all personnel understand site conditions and operating procedures, to ensure that personal protective equipment is being used correctly and to address associate health and safety concerns.

SURTREAT policies and procedures referenced in this Health and Safety Plan are located in the SURTREAT Comprehensive Health and Safety Manual and provide guidelines for proper safety protocol.

1.1 SITE HEALTH & SAFETY PLAN ACKNOWLEDGMENTS

The SURTREAT Field Project Manager (FPM) or a designated representative shall be responsible for informing all individuals entering the work area of the contents of this plan and ensuring that each person signs the Safety Plan Acknowledgment Form in Attachment H. By signing this form, individuals are recognizing the potential hazards present on-site and the policies and procedures required to minimize exposure or adverse effects of these hazards.

The information provided by this Site Specific Health & Safety Plan along with the SURTREAT Behavior Based Health and Safety System will be utilized to their fullest to protect our associates, our subcontractors, client, and the public from hazards associated with this project.

1.2 SITE HEALTH & SAFETY PLAN REVISIONS

The procedures presented herein are intended to serve as guidelines. They are not a substitute for the sound judgment of on-site personnel. Work conditions may change as the project progresses. As appropriate, addenda to the plan will be provided by the Health & Safety Coordinator. Additional field tasks with unique hazards or risks may be assessed and analyzed using a Job Safety Analysis Form located in the back of this plan. All changes to this plan must be approved by SURTREAT's Health & Safety Director and documented in Attachment A on the Site Specific Plan Amendment Form.

2.0 SITE BACKGROUND AND SCOPE OF WORK

2.1 SITE INFORMATION

Okinawa Japan Facility

2.2 SCOPE OF WORK

The scope of work for this project consists of surface preparation, treatment and application of repair materials and coatings. The following activities will be implemented to meet these objectives:

2.2.1 MOBILIZATION AND SITE PREPARATION

SURTREAT in coordination with MEC, CERL and Okinawa representative the Surtreat General Manager will mobilize the appropriate equipment and personnel to implement the required tasks within the scheduled timeframe. Mobilization and site preparation activities are described in detail below.

2.2.1.1 Site Security

During mobilization, signs will be placed where needed, limiting access to authorized personnel. SURTREAT will maintain, inspect and replace warning signs as appropriate during the execution of the work.

SURTREAT visitors will receive a site orientation discussing emergency procedures and hazards relating to the site as outlined by the Health & Safety Plan (HASP) and wear the appropriate personal protective equipment before entering work areas. All visitors will be required to sign the logbook, located inside the SURTREAT field office.

2.2.1.2 Support Facilities

SURTREAT will mobilize the necessary project personnel and equipment to the site to accomplish the scope of work. If necessary, an office structure (field office) will be established and will have the facilities to allow for direction of site operations, telephone and facsimile communications, a controlled environment for computer equipment, and a point of contact location..

2.2.1.3 Establishment of Work Zones

SURTREAT will establish work zones on the site prior to commencement of activities. The zones will be delineated by orange construction fencing and identified with signs. See Section 8.0 "Designated Work Zones" for detailed procedures. The work zones will include the following:

WORK ZONE

The work zone will encompass the areas where concrete work is being performed. It will include areas of the facility where excavation, demolition, surface preparation and treatment is taking place. The work zone may be adjusted in size as work is completed.

SUPPORT ZONE

The areas outside the work zone will be used as a support zone and will include areas for SURTREAT personnel and other site visitors to park vehicles and conduct activities outside of the work area. The support zone will also act as the area for the Daily Planning Health & Safety ("Tailgate") Meetings and act as a communication and coordination center for emergencies.

2.2.1.4 Equipment and Personnel Decontamination

Although equipment and personnel decontamination is usually not required in SURTREAT projects, appropriate provisions will be made if the need arises. Adequate restroom and wash facilities will be provided for workers in accordance with OSHA and Okinawa requirements and in compliance with Terms and Conditions of subject contract.

2.2.1.5 Utility Identification

SURTREAT will, prior to excavation if required, identify and mark all known utilities. Equipment operators will be notified of all possible hazards in regard to utilities (i.e., electric, gas, communications, water, sewer, and cable) prior to performing excavations. When utilities are identified in areas to be excavated, the excavation procedures will be conducted in a manner that minimizes the potential for disruption. This may include hand excavation around de-energized utilities, if necessary. Utility lines will be marked with flags or paint.

2.2.2 EXCAVATION AND HANDLING OF BROKEN CONCRETE AND SOILS

SURTREAT will utilize sound work practices when excavating and handling broken concrete materials and soil.

2.2.3 BIOLOGICAL HAZARDS

Biological hazards may be encountered at any site. The Field Project Manager will instruct the field crew of the applicable biological hazards during the site orientation and periodically throughout the project.

2.2.4 DEMOBILIZATION

Following completion of the work activities, SURTREAT will remove all equipment, materials, temporary facilities from the site. Waste materials generated during site activities will be properly disposed of at an approved off-site facility in accordance with local, state, and federal laws and regulations. Areas where remedial activities occurred will be left in a clean and stable condition prior to fully demobilizing from the site.

2.3 RESPONSIBILITIES

2.3.1 FIELD PROJECT MANAGER (FPM)

The SURTREAT Field Project Manager will be Max Merzlikin. The Field Project Manager will be responsible for directing all site personnel, equipment, subcontractors and activities to ensure a safe and successful implementation of the remedial action activities. All associates, including personnel not employed by SURTREAT, must participate in a site safety orientation prior to entering into the Work Zone. If there is any dispute with regards to health and safety, the following procedures shall be followed:

- Attempt to resolve the issue on-site with the Field Project Manager.
- If the issue cannot be resolved, then on-site personnel shall contact SURTREAT International for assistance and the specific task or operation in dispute shall be discontinued until the issue is resolved.
- The Field Project Manager is a key player in continuing and promoting SURTREAT's safety culture. The Field Project Manager's performance will be evaluated by his achievement of zero accidents and zero incidents.

2.3.2 HEALTH & SAFETY COORDINATOR

2.3.3 FOR MAJOR JOBS WITH EXTENSIVE SCOPE OF WORK, COMPLICATED TASKS OR PROLONGED SCHEDULES, SURTREAT WILL ESTABLISH A SITE HEALTH & SAFETY COORDINATOR. THE SITE HEALTH AND SAFETY COORDINATOR WILL BE ASSIGNED TO THE SITE ON A FULL-TIME BASIS WITH FUNCTIONAL RESPONSIBILITY FOR IMPLEMENTING THE SITE-SPECIFIC HEALTH AND SAFETY PLAN, AND THE SURTREAT COMPREHENSIVE HEALTH AND SAFETY MANUAL AS THEY APPLY TO SURTREAT. THE SURTREAT HEALTH AND SAFETY COORDINATOR WILL CONDUCT SITE AUDITS. SPECIFIC DUTIES INCLUDE, BUT ARE NOT LIMITED TO THE FOLLOWING:

- Assume responsibility for health and safety of SURTREAT personnel and promote SURTREAT's safety culture.
- Document safety problems and corrective actions.
- Ensure monitoring equipment is calibrated/operational.
- Perform respiratory fit tests.
- Inventory & inspect PPE prior to use.
- Prepare summary letter of personal air sampling results.
- Select protective equipment based upon this site-specific Health and Safety Plan, chemical properties, and air sample results.
- Prepare and maintain OSHA AND OKINAWA Log and documents required by Paragraph 11 in Terms and Conditions.

- Ensure that all SURTREAT personnel are fit for duty.
- Inspect first aid kits & fire extinguishers.
- Health and safety training and recognition.
- Report and investigate all accidents and near miss accidents.
- Coordinate safety orientation and daily safety meetings.
- Work with the Field Project Manager regarding work activities.
- Complete the Weekly Safety Report and forward it to SURTREAT's Health and Safety Director.

The Health and Safety Coordinator and the Field Project Manager will work together to promote a safety goal of zero accidents and zero incidents.

2.3.4 FIELD CONSTRUCTION CREW

- Will be responsible for asking questions and understanding the site-specific Health and Safety Plan.
- Report any unsafe or potentially hazardous condition to the Field Project Manager or the Health and Safety Coordinator.
- Comply with rules, regulations and procedures as set forth in this site-specific Health and Safety Plan.
- Express safety ideas or concerns in the daily safety meetings.
- Utilize stop work authority

2.4 KEY PERSONNEL

Principle Contractor:	SURTREAT HOLDING, LLC. 437 Grant Street 1210 Frick Building Pittsburgh PA 15219 412 281 1202 412 281 1282 Fax
SURTREAT Project Coordinator	Max Merzlikin Cell 585 303 2093

SURTREAT Field Project Manager (FPM)

SURTREAT H&S Coordinator (HSC)1

SURTREAT Health & Safety Director (HSD)

3.0 HAZARD EVALUATION

3.1 PHYSICAL HAZARDS

Physical hazards associated with surface preparation, treatment and other construction activities pose an equal or greater potential for injury at this Site than chemical exposure. Physical hazards can be posed by:

- **UNDERGROUND/OVERHEAD UTILITIES;**
- **HEAVY EQUIPMENT;**
- **NOISE;**
- **WEATHER;**
- **SLIP, TRIP, AND FALL;**
- **FIRE PROTECTION;**
- **TRAFFIC (heavy equipment, haul trucks; local traffic);**
- **Concrete cutting & removal;**
- **Manual application of material;**
- **Pressure washing**

Injuries that are possible from these physical hazards can range from simple slip-trip-fall types of accidents to casualties, including fatalities due to moving and/or rotating heavy equipment or electrocution. Injuries resulting from physical hazards can be avoided through the adoption of safe work practices and employing caution when working with machinery or around utilities and excavation areas. A safety attitude will translate into a safety behavior that is required by all personnel.

All field personnel shall be conscious of their work environment and should notify the Field Project Manager or Health & Safety Coordinator or other appropriate supervisory personnel of any unsafe conditions. The Field Project Manager or Heath and Safety Coordinator will ensure that all Site workers are informed of any physical hazards related to the Site. Several of these items have been discussed in Section 2.

3.1.1 UNDERGROUND/OVERHEAD UTILITIES

Before heavy equipment is utilized, all underground and overhead utilities (i.e., electricity, telephony, cable television, natural gas lines, water lines, sewer lines, etc.) will be identified and deactivated as needed. The deactivation of utilities, when necessary, should be certified by the proper utility company personnel and the certification record retained.

All overhead lines are to be treated as if they are energized unless de-energized by the person owning the line or the electrical utility authorities indicate that it is not an energized line and it has been visibly grounded; and no hoisted loads shall be left unattended.

If operation near overhead lines is necessary, the following table provides minimum clearance that is required for specific lines.

TABLE 3.1: REQUIREMENTS FOR EQUIPMENT OPERATION NEAR POWER LINES (29 CFR 1926.550)

ACTIVITY	LINE RATING	MINIMUM CLEARANCE
EQUIPMENT OPERATION	<50 kV	10 FEET
	> 50 kV	10 FEET + 0.4 INCHES PER EACH kV OVER 50 kV, OR 2 TIMES THE LENGTH OF THE LINE INSULATOR (MINIMUM OF 10 FEET)
IN TRANSIT WITH NO LOAD AND BEAM LOWERED	< 50 kV	4 FEET
	> 50 kV to 345 kV	10 FEET
	345 kV to 750 kV	16 FEET

Note: kV = kilovolts

3.1.2 HEAVY EQUIPMENT

Operation of heavy equipment presents potential physical hazards to personnel. Personnel protective equipment (PPE) such as steel-toe shoes, safety glasses or goggles, hearing protection, high visibility vests and hard hats should be worn whenever such equipment is present. Personnel should be aware at all times of the location and operation of heavy equipment, and take precautions to avoid the blind sides of the equipment operation. No one will travel within the swing radius of the equipment. Heavy equipment will be inspected daily.

3.1.3 NOISE

Heavy equipment and other construction activities may produce noise levels above acceptable standards. High noise levels can contribute to hearing loss as well as interfere with communication between workers. Exposure to noise can be expected when working around equipment and machines such as loaders and sweeping equipment, generators, compressors, concrete corers, jackhammers, etc.

Since the average noise level around heavy equipment will be over the 85 decibels established by OSHA AND OKINAWA, all personnel shall wear hearing-protective devices (i.e., either ear plugs or muffs with a NRR rating of at least 29) within 25 feet of such operating equipment, or when noise levels interfere with normal speech. Hand signals will be established by on-site personnel, as appropriate, to facilitate communications while involved in high-noise activities.

3.1.4 WEATHER

Adverse weather conditions are important considerations when planning and conducting Site operations. Hot weather, thunderstorms, and cold weather can cause physical discomfort, loss of efficiency, and personal injury and thus are factors that could affect this project. Whenever ambient air temperatures are below 50°F or above 70°F the following general practices will be followed:

3.1.4.1 Cold Weather Related Illnesses

HYPOTHERMIA

Hypothermia is defined as a decrease in the body core temperature below 96°. The body temperature is normally maintained by a combination of central (brain and spinal cord) and peripheral (skin and muscle) activity. Interference with any of these mechanisms can result in hypothermia, even in the absence of what normally is considered a "cold" ambient temperature.

FROSTBITE

Frostbite is both a general and medical term given to areas of local cold injury. Unlike systemic hypothermia, frostbite rarely occurs unless ambient temperatures are below freezing and usually less than 20°. Several steps will be taken to prevent cold related illness including:

- Educating workers to recognize the symptoms of frostbite and hypothermia;
- Identifying and limiting known risk factors;
- Assuring the availability of an enclosed, heated environment on or adjacent to the Site;
- Assuring the availability of dry changes of clothes;
- Assuring a capability for temperature recording at the Site; and
- Assuring the availability of warm drinks.

MONITORING FOR HYPOTHERMIA

Oral temperature recording at the job Site will be used to monitor for hypothermia. This will be done at the following times:

- At the supervisor's discretion (based on changes in a worker's performance);
- At the worker's request;
- As a screening measure, two times per shift, when hazardous conditions exist (wind-chill less than 0° or less than 30° with precipitation); and
- As a screening measure for all workers, whenever any worker on the Site develops hypothermia.

A core temperature of 95° is an indication of mild hypothermia and shivering and "goose bumps" are present. The single most important sign of hypothermia is a change in behavior.

MONITORING FOR FROSTBITE

Frostbite occurs most commonly to accrual parts (earlobes, nose, cheeks, and hands), which are distal to large muscle masses and subject to vasoconstriction. Three general types of frostbite are:

- Frostnip
- Superficial frostbite
- Deep frostbite

Frostnip exists as a whitened area of the skin or extremity. Slight burning or painful sensations may be present. A cessation of pain and feelings of warmth are indications of superficial frostbite. The skin may be waxy white and firm to the touch. Deep frostbite results in tissue

damage deeper than the skin. The appearance of the affected area is cold, numb, pale, and firm or hard.

TREATMENT OF FROSTBITE

Simple rewarming of frostnipped skin is definitive treatment. More extensive heating is needed to treat frostbite. The following specific procedures will be followed for cold-related illness:

- Treat the systemic hypothermia first, then the frostbite.
- Give hot liquids orally.
- Remove all covering from injured part. Do not break blisters.
- Do not attempt to thaw with dry heat. This is dangerous to frostbite tissue. Warm injured part in water from 104° to 110°. This should feel warm but not hot to an uninjured observer. Check temperature with thermometer.
- Seek immediate medical attention.

3.1.5 SLIP, TRIP, AND FALL

Material utilized in this process can become slick during application, proper footgear and a daily task review are required. Protection from slip, trip and fall hazards will be provided through standard safety procedures including good housekeeping. Properly locating equipment, regularly removing debris and taking general precautions during Site operations will be standard operating procedures. Workers will be apprized of any potential trip hazards through daily heath and safety meetings.

Whenever possible, trip and fall hazards will be eliminated or clearly identified with yellow "caution" tape. Impalement hazards to workers will be neutralized as soon as they are identified. SURTREAT and all subcontractors will be responsible for the use of safety belts, harnesses, lifelines, lanyards, safety nets, etc., for safeguarding their employees when performing elevated work in compliance with 29 CFR 1926.

3.1.6 IRE PREVENTION

Fire extinguishers shall be provided in fuel areas, storage areas, portable buildings and equipment. Safety equipment is checked on a routine basis, at a minimum of once per week. All extinguishers will be inspected, serviced, labeled and maintained. Any burning of materials is prohibited at the project Site. All flammable liquids will be marked and stored in a manner to conform to NFPA and OSHA AND OKINAWA requirements.

The use of power saws, torches and other spark or heat producing devices require a Hot Work Permit issued in accordance with applicable SURTREAT policy.

3.1.7 TRAFFIC

All traffic will follow typical construction safety practices. Specific on-site and off-site traffic routes will be established to accommodate construction activities. Necessary demarcation of routes, speed limits, and hazards will be made, as appropriate. As traffic routes are established or modified, the FPM or HSC will be notified and advise Site personnel during the routine health and safety meetings.

When working around traffic areas or when a higher degree of visibility is necessary, personnel will utilize orange traffic cones and safety vests.

Vehicles and equipment will be equipped and follow procedures as outlined in 29 CFR 1926.601. Operators are responsible for the vehicle or equipment they use and must be constantly aware of their surroundings. Vehicle traffic shall maintain a safe speed while operating on the Site. Vehicles will be equipped with an adequate audible warning device and have a reverse sign alarm audible above the ambient noise level. Vehicles and equipment will be inspected daily.

All construction traffic must follow Site protocol established for the work zone.

3.2 CHEMICAL HAZARDS

3.2.1 OVERVIEW

The chemical constituents that will be used on site are listed in Table 3.1.

TABLE 3.1: CHEMICAL EXPOSURE LEVELS FOR THE CHEMICALS OF CONCERN AT THE OKINAWA JAPAN FACILITY

CHEMICAL OF CONCERN	PEL mg/m³	TLV mg/m³	STEL mg/m³	IDLH mg/m³
TPS II	NO VOC			
TPS IV	NO VOC			
SURTREAT SARC	NO VOC			
TPS XII	120	121	N/A	
TPS XIV TPS XVII	NO VOC			
Surtreat Galvanic Coating	No VOC			

References

National Institute for Occupational Safety and Health (NIOSH) "Pocket Guide to Chemical Hazards", June 1997.

Occupational Safety and Health Administration (OSHA AND OKINAWA) permissible exposure limits (PELs), as found in Tables Z-1-A or Z-2 of the OSHA AND OKINAWA General Industry Air Contaminants Standard (29 CFR 1910.100).

"Sax's Dangerous Properties of Industrial Materials, Tenth Edition", by Richard J. Lewis, Sr., 2000.

Permissible Exposure Limits (PELs) are enforceable standards promulgated by OSHA AND OKINAWA and represent the 8-hour time-weighted average above which workers may not be exposed. In addition, "Action Levels" for some substances (e.g., lead) have been designated by OSHA. OSHA Action Levels are typically lower than the OSHA PEL for a particular substance, and are levels which, when exceeded, trigger certain air monitoring and medical surveillance requirements.

Threshold Limit Values-Time Weighted Average (TLV-TWA) values are the time-weighted average concentration for a normal 10-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. TLV-TWA are established by the American Conference of Governmental Industrial Hygienists (ACGIH, 1995) and provide the basis for safety regulations of OSHA AND OKINAWA.

Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) values are the concentrations to which workers can be exposed intermittently for short periods of time (15 minutes or less) without suffering from: 1) irritation; 2) chronic or irreversible tissue damage; or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded.

The Immediately Dangerous to Life or Health (IDLH) limit (NIOSH, 1997) is defined as the maximum concentration of toxic substance from which escape is possible without irreversible harm should a worker's respiratory protective equipment fail. The notation "Ca" means that NIOSH considers this substance to be a potential carcinogen. "N.D." indicates that an IDLH has not yet been determined.

3.2.2 CHEMICALS OF CONCERN

Based on available information, the chemicals of concern for this project are as follows:

- **TPS II**
- **TPS IV**

SURTREAT SARC

TPS XII

TPS XV

TPS XVII

SURTREAT GALVANIC COATING

Aesar Alumium Powder 11067

Aesar Magnesium Power 10233

Aesar Indium Powder 11024

Carboline Carbozin 11 Grey

Carboline Thinner 26

3.2.2.1 Diesel fuel

Synonyms: Number 2 Fuel Oil

Properties: A water-white, yellow to red oily liquid. Boiling point: 160–360°C (320-680^{0}F), flash point: 125–185°F, density: 0.80, lower explosive limit: 0.6%, upper explosive limit: 7.0%, autoignition temperature: 490°F, vapor density: >1.0. Insoluble in water; miscible with other petroleum solvents. A complex mixture of petroleum hydrocarbons, chiefly of the methane series. HMIS Hazard Rating: Health 1, Flammability 2, Reactivity 0, CAS: 68476-34-6, DOT Number: UN 1202, NFPA Rating 0-2-0.

Standards and Recommendations

NIOSH REL: (Kerosene) TWA 100 mg/m3
DOT Classification: 3; Label: Flammable Liquid

Safety Profile: A skin and respiratory irritant. Human systemic effects by inhalation: somnolence, hallucinations and distorted perceptions, coughing, nausea or vomiting, and fever. Aspiration of vomitus can cause serious pneumonitis, particularly in young children. Combustible when exposed to heat or flame; can react with oxidizing materials. Forms explosive vapors when exposed to heat or flame. When heated to decomposition it emits acrid smoke and fumes. To fight fire, use foam, CO2, dry chemical. Analytical Methods: For occupational chemical analysis use NIOSH: Naphthas, 1550. Class: Agricultural Chemical; Mutagen; Primary Irritant; Suspected. Reported in EPA TSCA Inventory.

3.2.2.2 *Gasoline*

Synonyms: Gas, motor fuel, petrol

Properties: A clear, light yellow, pink or red colored liquid with gasoline odor. Boiling point: 80-90^{0}F. Flash point: -45^{0}F. Lower explosive limit: 1.4%, Upper explosive limit: 7.6%. Solubility in water: Negligible. Vapors heavier than air. Comprised of a complex mixture of hydrocarbons including aromatics, ethers, alcohols and paraffins. NFPA Rating: 1-3-0. DOT: Flammable Liquid, UN1203.

Standards and Recommendations:

ACGIH TLV: 300 ppm (890 mg/M^3)

Safety Profile: A skin and respiratory irritant. Human systemic effects by inhalation: somnolence, hallucinations and distorted perceptions, coughing, nausea or vomiting, and fever. Aspiration of vomitus can cause serious pneumonitis, particularly in young children. May cause cardiac sensitization and anesthetic effects. Forms explosive vapors in air even at low ambient temperatures. To fight fire use foam, CO_2 or multipurpose dry chemical extinguishing agents.

3.2.2.3 *TPS II Proprietaryy Multi-phase, inorganic, surface applied corrosion inhibitor(a clear liquid with a sweet odor) for use on restoring concrete. Boiling point 212 deg. F., Spec. Grav. 1.1, Flash Point N/A since water based product, ph 12.0, solubility in water 100%,*

3.2.2.4 TPS IV Proprietary Multi-phase, inorganic, surface applied corrosion inhibitor with high solids content (a clear liquid with a sweet odor) for use on restoring concrete. Boiling point 212 deg. F., Spec. Grav. 1.1, Flash Point N/A since water based product, ph 12.0, solubility in water 100%,

3.2.2.5

SURTREAT SARC – *Proprietary coating, Viscosity 120 KU, Ph 13 Density* 11lb/gal, *Dilution Dilute with water.*

3.2.2.6 TPS XII Proprietary organic corrosion inhibitor applied to surface of concrete that penetrates to reinforcing steel level in liquid and vapor form to form a passivating film on the steel surface. Boiling Point 212 deg. F, Specific Gravity 1.03, flash point less than 212 deg. F, solubility in water 100%.

3.2.2.7

TPS XIV *Proprietary vapor phase migratory corrosion inhibitor admixture to reinforced concrete to inhibit reinforcing steel corrosion. Boiling Point 212 deg. F, Specific Gravity .96, Flash Point Non Flammable water based, pH 7.5 to 8.0.*

3.2.2.7 Galvanic Coating Materials

Aesar Alumium Powder 11067

Aesar Magnesium Power 10233

Aesar Indium Powder 11024

Carboline Carbozin 11 Grey

Carboline Thinner 26

See MSDS information.

AREA SAFETY & HEALTH RISK ANALYSIS

This section is to be addressed in the daily tailgate safety meeting and prior to the scheduled start of each new task to be performed. Each Area Specific Safety Assessment is designed to develop awareness to chemical and physical hazards specific to each task. It would be impractical to repeat in complete detail each control measure and SOP for each job task. Sources and hazards will be addressed for each job task with reference made to applicable control measures in Tables 4.1 – 4.9. When the Area Specific Safety Assessment is discussed, additional hazards may need to be addressed.

AREA SPECIFIC SAFETY ASSESSMENT - JOB SAFETY TABLE LIST

Table No.	Job Task	Hazard Rating	PPE Level
4.1	Mobilization / Site Preparation	Low	D
4.2	Excavation	N/A	D
4.3	Surface preparation	Medium	C
4.4	Concrete treatment	Medium	C
4.5	Mobilization	Low	D
4.6	Support zone activities	Low	D

3.3 *JOB SAFETY TABLE: MOBILIZATION / SITE PREPARATION*

PPE: LEVEL D HAZARD RATING: LOW

Hazard	Sources	Control Measures
Atmosphere	Airborne Contaminants from adjacent areas	Visually inspect area.
Manual Labor	Materials Equipment	Stretching and proper lifting techniques. Use of mechanical equipment or hand trucks utilizing a minimum of two people to lift loads over 50 pounds or awkward loads.
Slip/Trip/Falls	Various Sources	Housekeeping shall be done to keep work areas neat and orderly. Trip hazards will be marked or eliminated. Fall protection will be discussed in daily safety meetings.
Electrocution	Electricity	Only qualified electricians will be allowed to hook up circuits. Electrical lines (overhead and underground) will be located and marked. Extension cords will be inspected. Ground-Fault Circuit Interrupters (GFCIs) will be used on all electrically powered equipment.
Project Hazards	Physical and Chemical	Project hazards will be discussed in project orientation and continuing in daily safety meetings.
Electrical Shock Explosion	Overhead and Underground Utilities	All utilities will be marked and discussed in the Site orientation meeting.
Accidental Injury	Miscommunicati ons	Orientation meeting.
Miscommunication	Subcontractor	Site orientation.

3.4 *JOB SAFETY TABLE: EXCAVATION*

PPE: LEVEL D HAZARD RATING: LOW

Hazard	Sources	Control Measures
Atmospheric	Dust	Air monitoring as necessary.
Slips/Trips/Falls	Various Sources	Housekeeping shall be done to keep work areas neat and orderly. Recognized areas will be marked or eliminated.
Noise	Machinery	Hearing protection will be worn.
Heavy Equipment Injury	Machinery	Qualified operators, daily inspection of equipment. Operators will be aware of their surroundings. Area will be marked off.
Heat/Cold Stress	Weather	See Section 3.1.4.
Electrocution / Explosion	Underground / Overhead Utilities	All utilities will be marked prior to work beginning. Special classes will be conducted.
Road Traffic	Truck Entry and Exit	Flag person wearing orange vest if working within 10 ft of traffic area.
Excavation	Soil Excavation	Follow excavation procedures in Section 14.0.

3.5 *JOB SAFETY TABLE: SURFACE PREPARATION*

PPE: LEVEL C HAZARD RATING: MEDIUM

Hazard	Sources	Control Measures
Atmosphere	Dusts and chemical mists	Minimize generation of dusts with wet techniques. Respiratory protection.
Slip/Trip/Fall	Uneven terrain and working with hoses	Orderly housekeeping, work area clear of debris, hoses and equipment in good working order. Area properly barricaded.
Noise	Surfacing equipment & pressure washer	Hearing protection.
Manual Labor	Moving surfacing equipment	Mechanical equipment and two people working together.
Heat/Cold Stress	Weather	See Section 3.1.4.
Material Handling	Drums or Containers	Proper location and use of containers during mechanical removal.
High pressure water	Pressure washer	Proper PPE including faceshield

3.6 *JOB SAFETY TABLE: CONCRETE TREATMENT*

PPE: LEVEL C **HAZARD RATING: MEDIUM**

Hazard	Sources	Control Measures
Slip/Trip/Fall	Uneven terrain and working with hoses & rigging	Discuss in daily safety meeting. Discuss hazardous terrain. Provide the proper foot gear for the work area.
Manual Labor	Moving Small Equipment	Utilize two person teams. Utilize mechanical equipment whenever possible.
Heavy Equipment Injury	Machinery and rigging	Qualified operators, daily inspection of equipment. Operators will be aware of their surroundings. Area will be marked off.
Atmosphere	Chemical vapors	Respiratory protection.

3.7 *JOB SAFETY TABLE: DEMOBILIZATION*

PPE: LEVEL D **HAZARD RATING: LOW – MEDIUM**

Hazard	Sources	Control Measures
Traffic	Trucks and other equipment	Incoming and outgoing traffic.
Heat/Cold Stress	Weather	See Section 3.1.5.
Manual Labor	Materials Equipment	Stretching and proper lifting techniques use of mechanical equipment or hand trucks. Utilize "buddy system".
Slips/Trips/Falls	Various Sources	Housekeeping in good order; area will be kept neat and orderly.
Electrocution	Electricity	Only qualified electricians shall disconnect electrical circuits.

4.6 Job Safety Table: Support Zone Activities

PPE: LEVEL D HAZARD RATING: LOW

Hazard	Sources	Control Measures
Slips/Trips/Falls	Various Sources	Housekeeping in good order; area will be kept neat and orderly.
Heat/Cold Stress	Weather	See Section 3.1.5.
Traffic	Truck and Equipment	Flag person wearing orange vest if working within 10 ft of traffic area.

4.7 *PHYSICAL / ENVIRONMENTAL HAZARDS TABLE*

Hazard	Pre-Planning to Control Hazard	Active Control Measures
Biological	Insect Bites Mosquitoes, fleas, chiggers, biting ants, and spiders may exist near work sites. Tick Bites Tick season extends from Spring through summer. When embedded they might look like freckle. Snake Bites There may be poisonous snakes near work sites. If bitten by a snake, remain calm. Keep the affected area below the heart and walk, do not run, to the nearest first aid station. Apply ice or a cold pack and seek medical attention. Plants Poison ivy, sumac, and oak may be present on-site. Poison ivy can be found on tree trunks or as upright bushes. Poison ivy consists of 3 leaflets with notched edges. Two leaflets form a pair on opposite sides of the stalk, and the third leaflet stands by itself at the tip. Poison sumac has white, "hairy" clusters.	Apply insect repellant prior to field work. Wear protective clothing (work boots, socks, light colored clothing). Avoid walking in wooded areas and through bushes and tall grasses. Wear protective clothing (work boots, socks, light colored clothing). Check yourself often for ticks, particularly your lower legs and arms covered with hair. Spray outer clothing, particularly your pant legs and socks, but not your skin. Avoid contact with bushes and tall grass. If you suspect that a tick is present, remove it with tweezers, pulling gently. If it resists, cover tick with salad oil for about 15 min. to asphyxiate, and then remove. Look for signs of Lyme Disease, such as a rash that looks like a bulls-eye or an expanding red circle. Also look for signs of Rocky Mountain Spotted Fever, an inflammation that is visible in the form of a rash comprising of many red spots under the skin, which appears 3-10 days after the tick bite. Wear appropriate protective clothing. Be alert and aware of surrounding areas. Avoid walking in wooded areas and through bushes and tall grasses. Immediately wash skin thoroughly with soap and water if you come in contact with plants.
Electrical	Locate and mark existing energized lines. De-energize lines if necessary to perform work safely. All electrical circuits will be grounded. All 120-volt single phase, which is not a part of the permanent wiring, will have a ground-fault interrupter in place. Temporary wiring will be guarded, buried or isolated by elevation to prevent accidental contact be personnel or equipment. Evaluate potential for high moisture/standing water areas and define special electrical wiring needs.	Mark overhead and underground utilities.
Ergonomic	All operations evaluated for ergonomic impact. Procedures written to define limits of lifting, pulling, etc. Procedures to define how personnel will utilize proper ergonomic concepts and utilize mechanical material handling equipment. Necessary mechanical material handling equipment specified and ordered for project.	Proper body mechanics techniques stressed and enforced on a daily basis. Mechanical handling equipment maintained and utilized. Proper body mechanics stressed in scheduled safety meetings. Injuries reported and medically treated if in doubt about severity. Operations changed as necessary based on injury experience or potential.

Fire and Explosions	Ensure that properly trained personnel and specialized equipment is available. Define requirements for handling and storage of flammable liquids on-site, need for hot work permits and procedures to follow in the event of fire or explosion. Define the type and quantity of fire suppression equipment needed on-site. Coordinate which local fire fighting agencies to discuss unique fire hazards, hazardous materials, etc. Ensure Site operations comply 29CFR 1910.157G.	Inspect fire suppression equipment on a regular basis. Store flammable away from oxidizers and corrosives. Utilize hot work permit for all hot work on-site. Follow any Site-specific procedures regarding work around flammable. Review and practice contingency plans. Discuss on regular basis at scheduled safety meetings.
Flammable Vapor and Gases	Evaluate Site to determine sources of likely flammable gas or vapor generation. Develop specific procedures to be followed in the event of exposure to flammable. Specify specialized equipment needs for inerting flammable atmospheres, ventilating spaces and monitoring flammable concentrations. Define requirements for intrinsically safe equipment. Develop contingency plan to follow in the event of fire or explosion.	Calibrated monitoring equipment available and utilized by trained personnel whenever working where flammable gas or vapor is present. Monitoring performed at regular frequency and in all areas where vapor could generate or pool. Equipment and operations shut down when threshold levels are exceeded. Contingency plans reviewed regularly by all involved personnel. Work areas are carefully inspected to look for possible ignition sources. Sources are removed. Operations shut down is specific task procedures can't be followed to the letter.
Heavy Equipment Operation	Define equipment routes and traffic patterns for Site. Ensure that operators are properly trained on equipment operation for all equipment on project. Define safety equipment requirements, including backup alarm and roll over, for al equipment on-site. Implement SOP requiring operators to inspect equipment on a daily basis in accordance with safety and manufacturer requirements. Evaluate project requirements to ensure that equipment of adequate capacity is specified.	Equipment inspected as required. Equipment repaired or taken out of service. Ground spotters are assigned to work with equipment operators. Utilize standard hand signals and communication protocols. Personnel wear the proper PPE; utilize hearing protection, gloves for handling rigging, etc. Equipment safety procedures discussed at daily scheduled safety meetings. Personnel do not exceed lifting capacities, load limits, etc. for equipment. Personnel follow basic SOPs, which prohibit passengers on equipment, activating brakes and grounding buckets, securing loads prior to movement, etc.
Illumination	Evaluate all operations and work areas to determine lighting requirements. Specify specialized lighting requirements including explosion proof, intrinsically safe, lighting needs. Determine if nighttime outdoor operations are necessary. Evaluate tasks to be performed and number of light plants necessary to allow operations. Ascertain if outdoor lighting from nighttime operations will have an impact on surrounding communities.	Inspect specialized equipment and discard or replace as needed. Add additional lighting to areas with lighting. Inspect drop cords and portable lights on regular basis. Replace or repair as needed.
Noise	Local community noise standards examined. Expected loud operations evaluated to determine compliance with community standards. Loud operations scheduled for approved time periods. Noise level standards established for equipment brought onto Site. Hearing protection requirements defined for personnel expected to have excessive exposures.	Personnel receive annual audiogram. Personnel required to wear hearing protection. Defective equipment repaired as needed. Ongoing hearing conservation education promoted at scheduled safety meetings. Medical evaluation following noise (impact) exposure is symptoms present themselves.

Personal Injuries	Site operations will be evaluated for exposures with serious injury potential such as flying or falling objects, pinch points, falls from elevated surfaces, etc. A written fall prevention program will be developed if workers will be required to work at heights greater than 6 feet from unguarded work locations. PPE requirements will be based on potential for injury.	Personnel will wear required PPE. Specialized equipment such as rope grabs, winches, etc. will be inspected prior to each use. Defective equipment will be immediately replaced. All injury and near miss incidents will be reported to the HSC. First aid / CPR trained person on-site at all times. All injuries will be treated on-site with advanced medical treatment being sought if doubt about severity.
Small Equipment Usage	Site operations evaluated to determine need for specialized intrinsically safe, explosion-proof and UL approved equipment and instruments. Implement requirement for GFI, double insulated tool usage, or assured grounding program in all outdoor operations, will be utilized. Specific equipment needs to ensure that equipment used only for the purpose for which it was intended and to prevent abuse or misuse of the equipment. Specify requirements for the inspections and maintenance of specialized equipment. Specify that all equipment utilized on the project meets all OSHA AND OKINAWA requirements.	Perform first aid on-site as necessary. Transport for medical care if needed.
Trenching and Excavation	Implement excavation procedures if entry required into any excavation greater than 4 feet depth. Specify that competent persons assigned to project be present at all times personnel are in the trench. Specify that a Professional Engineer design specialized shoring systems for those that are extremely deep. Specify special PPE and monitoring requirements for excavations in soils contaminated with hazardous materials or gases and vapors. Ensure excavations comply with 29CFR 1926, Subpart P.	Competent person in the immediate area at all times that personnel are required to enter trenches. Operations shut down if the excavation shows any sign of cave in, excessive water; unacceptable levels of toxic contaminants, changing weather, or shoring systems have visible defects. Equipment operators keep all personnel inside excavation in sight. No suspended loads or movement of buckets over personnel. Regular monitoring is performed in excavations where toxic gases or vapors are possible.
Weather Conditions	Evaluate prevailing weather conditions for the Site. Contingency plans developed for likely severe weather conditions such as tornado and extreme thunderstorms. Provide for daily weather forecast service in extreme weather areas. Plan to weatherize safety systems, such as showers and eyewashes that would be impacted by extreme cold weather. Order necessary specialized cold weather clothing. Grounding and bonding requirements defined for thunderstorm areas. Sheltered air-conditioned break areas provided for extreme hot and cold weather zones.	Employees trained in contingency plan severe weather conditions. Emergency water sources inspected regularly in cold areas. Weather service contacted regularly during storm conditions. Supervisory personnel cease operations during extreme storm conditions. Personnel evacuate to safe assembly areas.

4.0 PERSONNEL

4.1 TRAINING

All associates of SURTREAT will receive classroom training on safe work practices at construction sites. All field personnel receive refresher training as needed:

- All assigned personnel will receive Site-specific training on routes of exposure and adverse health effects associated with the chemicals listed in Section 4.0, (Job Safety Tables).
- At least one member of each work crew shall be trained on emergency first aid and CPR procedures.
- At least one member of each work crew shall have training in the use of portable fire extinguishers in accordance with 29CFR 1910.157 (g).
- All subcontractors will receive a site safety orientation prior to entering the work zone.

4.2 MEDICAL SURVEILLANCE

Pursuant to 29 CFR 1910.134, all SURTREAT personnel required to utilize respiratory protection will receive a pre-employment medical examination, which includes a medical determination for respirator use.

5.0 SITE SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

Following levels of protection will be utilized at the Okinawa Japan facility

At a minimum, initial PPE requirements for concrete treatment activities will be Level D. The specific task analysis in Section 4 describes the level of protection for each task. PPE identified in Section 4 will be maintained until air-monitoring results or other observations indicate a change in PPE requirements. SURTREAT will be consistent with NIOSH minimum Level C or D depending on the task assigned.

PROTECTIVE GEAR	TYPE OR BRAND NAME	LEVEL C	LEVEL D
½ Mask Air Purifying Respirator	3M/North	✓	
Filters	P-100/organic	✓	
Protective Coveralls		✓ CHEMICAL RESISTANT	COTTON
Inner Gloves	Nitrile	✓	
Outer Gloves	Nitrile	✓	✓
Safety Shoes/Boots	Steel-Toe Leather	✓	✓
Boot Covers	Rubber	✓	
Hard Hat	Standard	✓	✓
Safety Glasses	Standard w/ Side Shields	✓	✓
Face Shield[1]	Standard	✓	✓
Goggles[2]	Standard	✓	✓
Hearing Protection[3]	Plugs/Muffs	✓	✓

[1] will be utilized when using high-pressure water or if splash of product exists.
[2] will be utilized when grinding or cutting (tinted lenses).
[3] will be utilized when noise levels exceed 85db

PPE will be upgraded:

- If new hazards are found with unknown toxic or physical hazards.
- If hazards exhibit higher toxic or physical hazards that, require upgrading of PPE.
- If associate requests an upgrade.

PPE will be downgraded:

- Only when analytical data and/or process knowledge justifies the downgrade.
- Downgrading requests must be in writing and approved by the FPM and SURTREAT's

HSD.

6.0 MONITORING

6.1 AIR MONITORING

Air Monitoring is not typically required for concrete treatment activities. However, should the need arise SURTREAT will coordinate these activities with the SURTREAT HSD and Okinawa Japan Safety Department.

Refer to Contractor Lineup Meeting No. 2

The major hazards of the work area and job are

Light Oil, Sub Gas, Sub2 Gas, RCM Training, Area Gas Check Required Daily by Okinawa Japan personnel.

Special precautions and/or conditions:

Close clearances w/roadway, alleyway, parking/equipment placement

7.0 DESIGNATED WORK ZONES

The Work Site will consist of work zone and a support zone.

7.1 SUPPORT ZONE

The support zone should be located upwind, if possible, and shall be secured against active or passive contamination from the work Site. The support zone will consist of those areas adjacent to the work zone where support trailers and equipment are staged. Eating and drinking will only be allowed in this area.

7.2 WORK ZONE

The work zone will be clearly marked off with caution tape. Appropriate warning signs to identify the work zone should be posted (i.e. DANGER - AUTHORIZED PERSONNEL ONLY). While in the work zone, personnel will wear appropriate PPE and refrain from horseplay, smoking, eating, drinking, and generating open flames.

7.3 GENERAL FIELD SAFETY

The following guidelines have been implemented and are constantly monitored and reviewed, to fully comply with SURTREAT's objective of keeping a safe and healthy work environment for all associates:

- Access to the property is restricted to authorized representatives. Entrance into the work zone will be limited to essential personnel.
- Anyone requesting access must receive authorization from the SURTREAT FPM prior to entry. All visitors shall be referred to the SURTREAT FPM.
- The work zone will be marked and "**AUTHORIZED PERSONNEL ONLY**" signs will be posted.
- A Visitors Log will be maintained at the field office. As a condition of admittance, all personnel agree to sign-in upon arrival and sign-out prior to departure.
- Visitors are only allowed in the work area with authorization and with appropriate levels of PPE.
- Beards or other facial hair that interferes with respirator fit will preclude admission in the work zone if it is determined to be a Level C operation.
- Smoking and tobacco products, eating and drinking will not be allowed in the work zone.
- Safety equipment described in Section 6 will be required for all field personnel.
- Personnel will only travel in vehicles where individual seats for each occupant are provided.

Seat belts will be worn if provided.

- Fire extinguishers will be available throughout the work area, especially in areas with increased fire danger such as the refueling area.
- Trackhoes or other equipment with booms shall not be operated within 10 feet of any electrical conductor.

8.0 HAZARD COMMUNICATION PROGRAM

Each contractor will be responsible for maintaining a copy of their Hazardous Communication Program and MSDS' on-site. However, the following items are specific to this job Site:

8.1 MATERIAL SAFETY DATA SHEETS

Material Safety Data Sheets will be maintained at the SURTREAT job trailer in the Hazard Communication Program Binder. MSDS' will be available to all personnel for review during the work shift.

8.2 CONTAINERS

All containers received on-site will be inspected by the contractor using the material to ensure that the containers are properly labeled with hazard warnings and manufacturer information. Secondary containers will be labeled utilizing the HMIS system.

8.3 CHEMICALS

All chemicals and other materials will be identified once the formal work plan and restoration program is determined.

8.4 EMPLOYEE INFORMATION

Prior to starting work, each associate will attend a health and safety orientation and will receive information on the following:

- An overview of the requirements contained in the Hazardous Communication Standard.
- Hazardous chemicals present at the Site.
- The location and availability of the written Hazard Communication Program.
- Physical and health effects of the hazardous chemicals.
- Methods of preventing or eliminating exposure.
- Emergency procedures to follow if exposed.
- How to read labels and review MSDSs to obtain information.
- Location of MSDS file and location of chemical list.

9.0 EMERGENCY RESPONSE PLAN

It is essential that Site personnel be prepared in the event of an emergency. Emergencies can take many forms: illnesses or injuries, chemical exposure, fires, explosions, spills, leaks, releases of harmful contaminants, or sudden changes in the weather. The following information should be posted as appropriate.

9.1 EMERGENCY CONTACTS

PRIMARY EMERGENCY NUMBERS

Fire, Ambulance, and Police

LOCAL HOSPITAL NUMBER

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SECURITY

SURTREAT KEY PERSONNEL

Name, SURTREAT Field Project Manager (FPM)

Additional Emergency Contacts

National Response Center

Center for Disease Control

CHEMTREC (Chemical Manufacturers Association) USA(800) 424-9300

9.2 COMMUNICATION

A mobile phone stays with the Field Project Manager at all times.

First aid kits

First Aid Kits and fire extinguishers are located on site and in the work vehicles. An eye wash and safety shower station will be located near the decontamination area but no more than 100 feet from the exclusion zone. The required content of first aid kits is listed in Attachment C.

9.3 ACCIDENT REPORTING

Refer to Attachment E or the Corporate Health & Safety Manual for Accident Reporting and Investigation procedures.

9.4 MEDICAL EMERGENCIES

Refer to Attachment G for the directions and map the hospital.

The FPM will prepare for medical emergencies prior to work starting on the project by:

- Driving to the nearest hospital from the work site to verify the travel route. Ensure that evacuation and hospital route maps are posted.
- Ensuring first aid kits are available and stocked.
- Ensuring that there is an adequate supply of cool potable water to be used in the prevention and treatment of heat stress.
- Ensure all emergency telephone numbers are posted including having quick access to associate's emergency numbers.
- Ensuring that there are adequate fire extinguishers available.
- Ensuring first aid trained personnel are on site.

9.5 FIRE

In the event of fire or explosion, or if vapor concentrations of explosive vapors or gasses approach or exceed (shall not exceed) 10 percent of the LEL as indicated by an explosion meter, personnel will quickly evacuate the area and the local fire department should be summoned immediately.

Upon their arrival, the SURTREAT Field Project Manager will advise the fire commander of the location, nature, and identification of any hazardous materials on site.

SURTREAT shall provide protection from fires in the form of portable fire extinguisher. This protection shall meet or exceed the requirements of NFPA-10-1984.

9.6 SPILLS

In the event of a spill, site personnel should locate the source of the spill and stop the flow if it can be done safely. A containment area should be constructed to recover the spilled materials and prevent migration.

9.7 EVACUATION

In the unlikely event of a leak or spill of toxic or hazardous materials., immediate work area evacuation directed by the FPM, must be spontaneous. Immediate phone contact from the field to an outside emergency contact as instructed by MEC, CERL and local Okinawa representatives.

- Evacuation routes are established for all work zones. The maps will be posted in the main break area where morning health & safety tailgate meetings are held. Changes will be review as made due to construction changes & atmospheric conditions.
- All outside work areas have been provided with designated exit points.
- Evacuation should be conducted immediately, without regard to equipment under conditions of extreme emergency.
- Evacuation notification will be three (3) blasts on an air horn, vehicle horn, or by verbal communication on radios.
- Keep upwind of smoke, vapors, or spill location.
- Exit through the decontamination corridor is possible.
- If excavation is not via the decontamination corridor, site personnel should remove contaminated clothing once they are in a location of safety and leave it near the exclusion zone.
- The SURTREAT Field Project Manager will conduct a head count to ensure all personnel have been evacuated safely.
- In the event of an emergency evacuation, all personnel should meet at the pre-determined assembly location.

9.8 EVACUATION RESPONSIBILITIES

As the administrator of the project, the SURTREAT Field Project Manager has primary responsibility for responding to and correcting emergency situations. SURTREAT's representative will:

- Take appropriate measures to protect personnel including: withdrawal from the work area, total evacuation and securing of the site or upgrading or downgrading the level of protective clothing and respiratory protection.
- Take appropriate measures to protect the public and the environment including isolating and securing the site, preventing run-off to surface waters and ending or controlling the emergency to the extent possible.
- Ensure that appropriate federal, state, and local agencies are informed, and emergency response plans are coordinated. In the event of a fire or explosion, the local fire department should be summoned immediately. In the event of an air release of toxic materials, the local authorities should be informed in order to assess the need for evacuation. In the event of a spill, sanitary districts and drinking water systems may need to be alerted.
- Ensure that appropriate decon treatment or testing for exposed or injured personnel is obtained.
- Determine the cause of the incident and make recommendations to prevent the recurrence.
- Ensure that all reports have been prepared.

The FPM must immediately take measures to protect site personnel and to immediately report the incident to SURTREAT's Health & Safety Director.

10.0 CONFINED SPACE

A confined space is defined as a space or work area not designed or intended for normal human occupancy, having limited means of egress. Examples include tanks, vats, and basements. The entry permit form is located in the back of this Plan will be utilized for entry in any Permit Required Confined Space. Confined spaces will be identified below during site preparation and during site activities as they are discovered.

10.1 TYPE OF CONFINED SPACE & LOCATION

Although there are no anticipated confined space entries planned, conditions at the site may necessitate entry into confined spaces. Only properly trained and qualified personnel will enter a permit required confined space.

11.0 EQUIPMENT SAFETY

The following equipment safety standards are applicable for equipment and vehicles owned or leased by SURTREAT and their subcontractors. Safety Standards are divided into two categories, heavy equipment and vehicles. Heavy equipment includes rubber-tired and crawler type excavation and materials handling equipment and haul trucks. Vehicles include pick-ups, passenger vans and cars.

11.1 HEAVY EQUIPMENT

Heavy equipment anticipated for this site includes the following:

N/A

11.1.1 GENERAL REQUIREMENTS

PARKING: All equipment left unattended at night, adjacent to a roadway in normal use, or adjacent to active construction areas, shall have appropriate lights or reflectors, or barricades with appropriate lights or reflectors, to identify the location of the equipment. Bulldozer blades, end-loader buckets, dump bodies, and similar equipment shall either be fully lowered or blocked when being serviced or not in use. All controls shall be in a neutral position, with the motors stopped and the brakes set.

AUDIBLE ALARMS: All heavy equipment shall be equipped with a reverse signal alarm. The alarm shall be distinguishable from the surrounding noise level, and shall be maintained in an operable condition.

OPERATOR CABS: All equipment with operator cabs shall be equipped with windshields and power wipers. All cab glass shall be safety glass, or equivalent, that does not introduce visible distortion affecting operation. Cracked and broken glass shall be replaced.

SEAT BELTS: Seat belts shall be provided in all equipment. Operators will be required to wear seat belts while the equipment is in operation. Seat belts are not required for equipment, which is designed for stand-up operation.

RIDERS: Only qualified equipment operators will be allowed on the equipment when it is in operation. Associates will not be allowed to ride on the equipment.

11.1.2 UNDER POWER LINES

Except where electrical distribution and transmission lines have been de-energize and visibly grounded at the point of work or where insulating barriers have been erected to prevent physical contact with the lines, equipment shall be operated in accordance with the following:

A fifteen (15) foot fallback line will be utilized on all underground and overhead utilities. Underground utilities will have concrete monuments placed around them restricting access. All overhead poles will also have monuments placed around them.

11.1.3 ROLL-OVER PROTECTION (ROPS)

All rubber-tired and crawler type equipment owned or leased by SURTREAT and any subcontractors shall be equipped with roll-over protective structures which meet the minimum performance standards, as prescribed in 29 CFR1926.1001 and 1926.1002.

11.2 VEHICLES

11.2.1 GENERAL REQUIREMENTS

BRAKES: All vehicles shall have a service brake system, an emergency brake system and a parking brake system. These systems may use common components and shall be maintained in working order.

LIGHTING: All vehicles shall be equipped with two headlights and two taillights, and shall be maintained in working order. All vehicles or combination of vehicles shall have brake lights in operable condition.

SEAT BELTS: Seat Belts meeting DOT regulations shall be maintained in all vehicles. SURTREAT associates will be required to wear their seat belts when operating or as passengers in company vehicles.

LOADS: Materials and tools will be firmly secured to prevent movement when transported in the same compartment with SURTREAT Associates.

AUDIBLE ALARMS: No associate shall use any vehicle having an obstructed view of the rear unless:

- The vehicle has a reverse signal alarm audible above the surrounding noise level; or
- The vehicle is backed up only when an observer signals that it is safe to do so.

ATTACHMENT A - SITE SAFETY PLAN AMENDMENT FORM

<table>
<tr><td>OKINAWA JAPAN FACILITY</td><td>Amendment Number:</td></tr>
<tr><td>Date:</td><td>Type of Amendment: ADDITION</td></tr>
<tr><td colspan="2">Reason for Amendment:</td></tr>
<tr><td colspan="2">INCLUSION OF OKINAWA JAPAN WORKS Safety Requirement, Contractor Lineup Meeting of</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Alternate Safeguard Procedures:</td></tr>
<tr><td colspan="2"></td></tr>
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<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Required Changes in PPE:</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Signatures:</td></tr>
<tr><td>SURTREAT FIELD PROJECT MANAGER</td><td>Date</td></tr>
<tr><td>SURTREAT SITE HEALTH & SAFETY DIRECTOR</td><td>Date</td></tr>
<tr><td>OWNER ON-SITE REPRESENTATIVE</td><td>Date</td></tr>
</table>

ATTACHMENT B - PERSONNEL PROTECTIVE EQUIPMENT POLICY

In conditions where a hazard exists, the ideal work environment would be achieved by the use of engineering controls such that the control utilized would either completely remove all hazardous materials/conditions from the work place or fully isolate associates from hazardous materials/conditions. An example of an engineering control is dust suppression accomplished by sprinkling dry, dusty soil with water. Whenever engineering controls can be proven effective and feasible, they will be initiated.

SURTREAT Personal Protective Equipment Policy shall be consistent with NIOSH recommendations. It is anticipated that much of the concrete related activities will be conducted in level D.

Any personal protective equipment issued to the associate by the company is the personal responsibility of the associate. He/she must ensure that it is kept in a safe and clean condition and in his/her possession at job Sites. When in disrepair, it must be returned for repair or replacement.

In certain construction and maintenance operations, personal protective equipment, such as safety glasses, chemical goggles, respirators, hard hats, and protective clothing is required. The type of protective equipment to be worn will be determined by the degree of exposure to the potential hazard. When in doubt about the safety measures to be observed, associates shall contact the supervisor.

While personal protective equipment reduces the potential for contact with harmful substances, ensuring the health and safety of workers requires, in addition, safe work practices, decontamination, Site entry protocols, and other safety considerations. Together these protocols establish a combined approach for reducing potential harm to associates.

Personnel must wear protective equipment when response activities involve known or suspected atmospheric contamination, when vapors, gases or particulate may be generated, or when direct contact with skin-affecting substances may occur. Respirators can protect lungs, gastrointestinal tract, and eyes against air toxicant. Chemical-resistant clothing can protect the skin from contact with skin-destructive and absorbable chemicals. Good personal hygiene limits or prevents ingestion of materials.

The materials of concern present at the Site have been established by laboratory analyses of samples obtained from the job Site. The selection of sample media and locations shall be on the basis of those media and locations anticipated to be of greatest concern. A risk analysis has been performed for each material of concern in order to identify the material(s) of greatest concern. The appropriate protective ensemble will be selected on the basis of the risk analysis.

In addition to risks due to contaminants, some physical hazards or hazardous conditions may be present in the work area. These include risk of injury while working around heavy equipment, manual lifting, hearing damage from heavy equipment noise, and heat or cold stress.

PPE LEVEL C with coated tyvek suit or cotton coveralls includes the following items at a minimum:

- One piece chemical resistant coated tyvek suit with hood and enclosed feet or one piece cotton coveralls
- Inner gloves; latex
- Outer gloves; cotton
- Rubber boots/safety- toed
- Half-face, dual cartridge, air purifying respirator with cartridges
- Safety harness and rope
- Hearing protection
- Hard hat
- Safety glasses with side shields
- Face shield (when using high pressure water equipment)

PPE LEVEL D includes the following items at a minimum:

- One piece protective cotton coveralls
- Hard hat
- Safety glasses with side shields
- Work gloves – if required
- Hearing protection – if required
- Safety boots

EYE PROTECTION is required when engaging in such operations as the following:

- Drilling, chipping, grinding, wire brushing
- Handling caustics and acids
- Breaking bricks and concrete
- Power washing
- At least number 2 shaded eye protection for burning and oxy/gas welding.
- Other situations which create a possible eye hazard, e.g., chemical applications

The following are different types of eye protection used:

- Industrial type safety glasses must be worn. Monogoggles will be worn over regular prescription glasses, if the glasses are not ANSI rated.
- A full-face shield must be worn while performing any job with high-pressure water. A face shield is not to be substituted for safety glasses or goggles, but used in addition to them.
- Chemical splashguard goggles are required on all operations where solvents, acid, or caustics are used or in the immediate vicinity.
- Appropriate goggles must be worn at any time a hazard exists, such as grinding or chipping operations or welding.

- Sandblasting hoods with plastic face shields and piece protection are required while operating a sandblast gun or nozzle. These must be positive pressure fresh air hoods.

EAR PROTECTION: Ear plugs or muffs are required on assignments where the noise level is above 85 dBA on an average of eight hours worked. If noise is a problem, workers must wear hearing protection.

HAND AND BODY PROTECTION: Waterproof gloves, wet suits, and rubber boots will provide some protection. Where conditions warrant, additional protection such as acid suits, chemical gloves, metatarsal guards or shin guards must be worn. Personnel using arc welding equipment will comply with 29 CFR 1926.102 and will wear a long sleeve shirt, gloves, head protection, and using a welding hood with a sufficient shaded lens for the type of welding being performed.

FULL-BODY HARNESS AND LIFELINES: Whenever any associate is exposed to the hazard of falling six feet or more, he must wear a serviceable harness and lifeline adequately secured to a fixed support. This will be so arranged that he cannot fall freely from a vertical distance more than three feet. This included any associate working on open steel, swing stages, suspended scaffolds, platforms without proper guarding, etc.

- When working on a swing stage or elevated device, the lifeline must be secured to a structure separate from the stage or elevating device.
- All safety harnesses, lifelines and lanyards are to be inspected before use for fraying or other weak spots. Any defective item must be replaced before using.
- Safety harness must be in good condition and the "D" ring must be placed in the back.
- Bolts, shackles, safety snap hooks, "D" rings and metal links which connect parts of the lifeline system to each other should be properly inspected and maintained at all times.
- Safety harness and lifelines are required on all work performed in confined spaces where an oxygen deficiency or toxic vapors may exist.

BACK SUPPORT HARNESSES: When any associate is required to move or lift any materials, dollies, forklifts, pallet jacks, back harnesses, and proper lifting techniques should be utilized. Proper lifting techniques are taught to all associates during training sessions and are as follows:

- Put on a back harness support
- Get a good footing on a solid surface
- Place one foot alongside and the other behind the object
- Squat down beside the object keeping your back as straight as possible
- Tilt the object and firmly grasp at the bottom center
- Draw the object close to your body, lift slowly by straightening your legs
- Do not lift more than you can carry. Get help with bulky or heavy loads.

ATTACHMENT C - FIRST AID TREATMENT

PROCEDURES FOR EMERGENCY MEDICAL AND FIRST AID

In the event of personal injury, a Site associate trained in first aid will administer treatment to the injured worker. If necessary, the injured worker will be transported to the nearest hospital. (For all areas, emergency arrangements will be made prior to the commencement of work at the project.) An ambulance will be provided if necessary. The Field Project Manager is responsible for the completion of an Accident Report Form.

OSHA AND OKINAWA Subpart K, Medical Services and First Aid, states that an employer shall ensure that medical personnel are readily available for consultation if professional assistance is not in near proximity to the workplace, persons will be adequately trained to render first aid. SURTREAT requests that at least one person for every ten employees working are trained in first aid procedures and cardiopulmonary resuscitation (CPR).

SURTREAT advises the following procedures in case of an accident, however these recommendations are not a substitution for First Aid Training:

- Evaluate the situation and take immediate appropriate action. If necessary, remove the victim from a hazardous environment.
- Make certain help has been obtained from an appropriate source.
- Ascertain that the victim is breathing. If not, begin artificial respiration. Make sure the breathing passages are not blocked.
- Stop bleeding. Follow proper decontamination procedures prior to removing a victim contaminated with hazardous substances. If the victim is not decontaminated, other people and areas could be contaminated.
- Double check that help is on the way.
- Communicate accurate information concerning details of the accident to medical personnel. It is very important that the medical personnel understand what type of chemicals to which the victim may have been exposed. The SURTREAT office is equipped with specific chemical information and first aid guidelines to assist you and the medical personnel. This information can be accessed and relayed to the hospital or medical personnel within minutes.

ORDER OF OBTAINING FIRST AID

If possible, designate another person to go for assistance while you stay with the victim.

- Notify a physician, make him/her aware of the emergency and follow his/her advice regarding further first aid and transportation of the victim.
- If it is apparent that the services of an ambulance are necessary, tell the telephone operator it is an emergency and ask him/her to connect you with the local ambulance service. If there is no ambulance service, telephone the nearest city, county, or state police.
- In the telephone request to the doctor, police, or ambulance, be prepared to give:

- The phone number you are calling from
- The address and directions to the Site
- A description of the accident, number of victims and condition
- Your name

- Do not hang up until emergency personnel end the conversation
- Stay at the Site until the doctor or ambulance arrives.

CONDITION, SYMPTOMS AND TREATMENT

BREATHING – BREATHING STOPPED ENTIRELY:

- Determine victim is not breathing by opening airway, examining mouth for foreign object, look, listen and feel for 10 seconds.
- Deliver two rescue breaths, using CPR barrier.
- Check carotid artery for pulse – if victim has a pulse, continue delivering one rescue breath every five seconds for approximately one minute. If pulse is not present, begin chest compressions at a rate of 15 compressions: 2 breaths.
- Continue until pulse & breathing return or until relieved by someone with equal or greater training.

SHOCK - PALE SKIN, BODY CLAMMY AND COLD, PULSE RAPID AND WEAK

- Keep victim lying down.
- Maintain normal body heat, but do not allow victim to become overheated.
- If victim's face is pale, elevate feet slightly.
- Reassure victim.

BLEEDING - BLOOD FLOWING

- Wearing nitrile or latex gloves, apply direct pressure, elevate.
- For profuse bleeding, use pressure points in either armpit or groin areas.

ELECTRICAL SHOCK - UNCONSCIOUSNESS, BURNS MAY BE PRESENT, MAY CONVULSE

- Survey the situation carefully. Make certain you are not the second victim.
- If possible, turn power off.
- If unable to turn power off move person from contact by moving live wire with a rope or dry board. If the victim remains in contact with the source of the electricity and must be moved use only your feet. By using your hands an electrical current is sent through your entire body including your heart and is far more serious than current through the legs. An electrical current through the lower extremities is rarely fatal.
- Check breathing. Check pulse. If necessary, begin CPR. Do not stop life saving measures until medical personnel arrive.

BURNS

- 1ST DEGREE - skin reddened – apply cool water for 20 minutes.
- 2ND DEGREE - skin blistered – apply water-based burn gel and cool for 20 minutes.
- 3RD DEGREE - deep destruction of tissue usually with charring – apply water-based burn gel, cover with sterile, non-stick dressing (gauze impregnated with water based gel is ideal).

FRACTURES

- Simple - pain and swelling, and/or deformed part.
- Open - broken bone plus break in skin and bleeding.
- Immobilize fractured part.
- Stop bleeding and dress wound.
- Arms and hands need to be immobilized for transport to medical facility.
- First aid providers should not splint other bones. EMS is better equipped to transport victims. Apply ice, treat for shock, and try to relieve anxiety while waiting for arrival of EMS.

SPINAL INJURIES

Injury to the back, neck or head should be suspected in any accident involving a fall, impact trauma (MVA), falling object or any injury with loss of sensation and/or movement. Move the victim only if necessary. Attempt to keep the body aligned and the back and neck straight. Preferably, the victim should not be moved until an ambulance arrives with a special stretcher and trained personnel.

CHOKING

Violent choking, alarmed expression, attempts at inhalation, discoloration in the face, neck, and hands, unconsciousness.

- As long as the victim is coughing, stand by.
- If the victim ceases coughing, uses universal sign of choking, is unable to respond or speak: identify yourself and offer your assistance.
- Notify rescue squad.
- Stand behind victim, place fist of one hand in position mid way between the victims umbilicus and rib cage.
- Place other hand on top of the fist, and make quick sharp inward thrusts until the foreign object is expelled, or the victim loses consciousness.
- If the victim becomes unconscious, lower gently to the floor, check mouth for object, attempt rescue breath. If airway is still obstructed, straddle victim over the hips, and deliver approximately 5 upward, inward thrusts midway between the umbilicus and rib cage.
- Continue to attempt to give rescue breaths.
- If unable to get air into the victim, repeat abdominal thrusts.

- If object becomes dislodged, remove it from the mouth, open the airway with chin lift, head tilt, and check for spontaneous breathing.
- If victim does not breath spontaneously once the obstruction is removed, give two rescue breaths, then check for pulse. If there is none, initiate chest compressions.
- If pulse is present, but victim is not breathing, deliver rescue breathing only.

SUDDEN ILLNESS

HEART ATTACK - Chest pain, shortness of breath, pale or bluish skin, shock.

- If person demonstrates symptoms of heart attack for more than 10 minutes call EMS. If patient has a history of heart disease, allow them to use their medication, then wait three minutes only for alleviation of symptoms before calling EMS.

STROKE - Loss of sensation and/or movement on one side of the body, pupils unequal, inability to talk, unconsciousness.

SEIZURE - Rigidity of body muscles lasting from a few seconds to half a minute, bluish discoloration of face and lips.

- Following seizure, open airway with chin lift, and check for breathing. If victim has a history of seizure, EMS is not needed if he/she recovers spontaneously. If seizure occurs in individual with no known seizure history, EMS must be called.

FAINTING - Unconsciousness

- Check breathing. Check pulse. Begin CPR, if necessary.
- Loosen tight clothing.
- Keep normal body temperature.
- In the case of seizure - protect the victim from injury, but do not attempt to place objects in the victim's mouth.
- Do not attempt to give an unconscious victim liquids.

PREVENTION OF HEAT STRESS

PROPER CLOTHING - Loose fitting, lightweight, light colored, and properly ventilated.

HAT - To prevent radiant heat exposure to the head and to shield the face from ultraviolet light.

ACCLIMATIZATION - Heat disorders are more likely to occur at times when workers are unacclimatized to working in the heat. Most people require one week to adapt to a hot humid environment.

WORK LOADS - During hot temperatures, workloads should be adjusted to each worker's acclimatization rate.

BODY WEIGHT - Monitor your daily weight. A pint of water weighs one pound. If you have lost several pounds in one day, try to replace the amount of weight lost.

HEART RATE AND BODY TEMPERATURE - While working in the heat your heart rate and body temperature are good measures of body stress.

FLUID INTAKE - The most important measure of prevention adequate fluid intake during the work period.

Symptoms	Treatment
Heat Stress: Rapid heart beat Heavy sweating Discomfort Fatigue	 Additional rest periods Plenty of water to drink.
Heat Exhaustion: Pale, cold, clammy skin Rapid, weak pulse Weakness, headache or nausea Cramps in abdomen Excessive perspiration	 Move victim to cool shade Make victim lie down with head lower than the rest of the body Give victim water to drink Get medical help
Heat Stroke: Flush, dry, hot skin Rapid, strong pulse Skin feels hot to the touch, temperature well above normal Headache, dizziness, nausea Often the victim is unconscious	 Move victim to cool shade Treat for shock Cover entire body with cold water Give victim water to drink if conscious Get medical help

EXPOSURE TO HAZARDOUS CHEMICALS

The environmental industry is faced with the problem of handling mixtures of unknown substances. Speed is of prime importance in the prevention of injury from chemical exposure. It may not be possible to take the time to determine what particular chemical or combination of chemicals is responsible for the exposure. Even if a chemical is known it may require valuable time to refer to specific chemical exposure guidelines. If the "worst case" exposure guidelines are followed, then valuable time can be saved. In general, there are four ways that chemicals enter the body: inhalation, skin exposure, eye exposure, and ingestion.

INHALATION

- Remove from hazardous area to fresh air.
- If not breathing, begin mouth-to-mouth respiration.
- Give oxygen.
- Call emergency services.
- Identify chemicals.
- Observation by physician for a 24-hour period depending on specific chemical.

SKIN EXPOSURE

- Remove contaminated clothing.

- Wash under running water for 15 minutes.
- Call emergency services.
- Identify chemical
- Observation by a physician if necessary.

Eye exposure

- Wash eye for 15 minutes (remove contact lenses first).
- Call emergency services.
- Identify chemicals.
- Evaluation and treatment by physician.

Ingestion

- Identify chemical ingested.
- Call poison control center, Okinawa Japan contact and/ or CHEMTREC USA 800-424-9300.
- Follow actions given by center.
- Seek follow-up medical attention if recommended by the center.

First Aid Kit

The required contents for first aid kits for outdoor use as specified in ANSI 308.1 (1999) is as follows:

- 6 sterile eye pads
- 1 scissors and tweezers
- 1 triangular bandage
- 16 adhesive bandages
- 1 roll adhesive tape
- 1 gauze roller bandage
- 1 large compress
- 1 antiseptic
- burn gel
- 4 sterile gauze pads
- 1 bottle eye wash
- 1 sting relief
    - 2 pair latex gloves
    - 1 eye shield / mask
    - 1 paper gown
    - 1 disinfectant

ATTACHMENT D - ALCOHOL & DRUG POLICY

SURTREAT strives to provide a safe and healthy work environment and protect its operations and facilities. It is the objective of SURTREAT to maintain a productive and efficient work place. Therefore, SURTREAT policy prohibits the unlawful manufacture, distribution, dispensation, possession, use, or being under the influence of a controlled substance in the work place. Any associate found to be in violation of this policy shall be subject to discipline, up to and including discharge.

SURTREAT's Substance Abuse Policy was created to establish and maintain a safe and healthy work environment for its associates as mandated by the Drug-Free Work Place Act of 1988. "Drug" is defined as any substance, other than alcohol, capable of altering an individual's mood, perception, pain level or judgement. "Controlled Substance" is defined as any substance, which can be legally obtained only by prescription by a licensed medical practitioner. "Illegal Drug" is defined as any drug or controlled substance that is generally recognized as illegally sold or consumed.

All applicants for employment will be advised of SURTREAT's Drug and Alcohol Policy. A medical screen for drugs is a condition for employment and will be included in the pre-employment physical examination. Positive tests serve as grounds for denial of employment and/or termination. Associates who refuse a medical screen may be denied employment. The Drug and Alcohol Policy allows SURTREAT to require an associate to submit to a drug and alcohol test at any time, without prior notice. SURTREAT may refuse to hire an applicant who does not sign an agreement consenting to future drug and/or alcohol testing in accordance with company policy.

All associates are expected to abide by the terms of the Drug and Alcohol Policy as a condition of employment. Additionally, all associates are required to notify their immediate supervisor if they are convicted under any criminal drug statute for a violation occurring in the work place no later than five (5) days after the conviction. If an associate is convicted under any criminal drug statute for a violation occurring in the work place, SURTREAT may at its discretion take appropriate personnel action against the associate, up to and including immediate discharge, and/or require the associate to satisfactorily participate in a drug abuse assistance program.

The following guidelines are mandatory for all SURTREAT associates:

- The use of illegal drugs is prohibited.
- All associates are prohibited from being under the influence of alcohol, illegal drugs, or any drug not legally prescribed during working hours.
- The use, sale, purchase, possession, or transfer of any controlled substance other than use as prescribed by a physician while performing company business, on or off company premises, is strictly prohibited and grounds for immediate dismissal.
- No alcoholic beverages will be bought or consumed on company premises except in connection with company sponsored events. Violation will result in disciplinary action, up to and including dismissal.
- Associates suspected of being under the influence of alcohol or any illegal drug during

working hours, will be suspended immediately and will be required to take a medical screen for drugs.

The SURTREAT Drug and Alcohol Policy, serves as protection for both SURTREAT and its client. Therefore, compliance with the stated guidelines is mandatory and will ensure a safe, healthy work environment and reduce substance abuse related accidental injuries to person and property.

ATTACHMENT E - ACCIDENT REPORTING

SURTREAT is guided by an established safety policy. This policy is based on a sincere desire to eliminate personal injuries, occupational illnesses, and damage to equipment and property, as well as to protect fellow associates and the general public whenever the public comes in contact with, or is affected by, the Company's work.

SURTREAT recognizes associates and implement safety procedures. Those associates who avoid injury and any vehicle accident are recognized on an annual basis. In addition, other incentive programs are implemented and include programs such as short-term safety contests, whereby prizes are awarded to associates with exceptional safety records. It is the responsibility of the SURTREAT Health and Safety Director to determine such additional incentive programs and/or contests.

SURTREAT shall provide a verbal report of all reportable accidents, as soon as the injured associate's immediate needs are attended to, a verbal report of all injuries that require medical attention or loss of work time. A written report to the oversight safety inspector shall follow within twenty four (24) hours. In the event of severe injury, death or extensive property damage, SURTREAT shall notify and assist oversight investigation team during the inquiry. SURTREAT shall maintain a log of occupational injuries and illnesses as required by federal law in accordance with the OSHA AND OKINAWA record keeping requirements of 29 CFR 1904.2

Completed accident documentation appropriate for the accident shall be maintained on-site and include the following forms / reports / summaries:

- Employer's First Report of Injury or Illness
- Medical Treatment Authorization
- Major Incident Report
- Automobile Loss Notice
- General Liability Loss Notice
- Motor Carrier Accident Report
- First Aid Register
- Monthly Accident Analysis
- Monthly Preventable Accident Monthly Summary

Copies of the Employer's First Report of Injury or Illness shall be submitted to oversight safety inspector and construction foremen.

Managers and supervisors are charged with the responsibility of preventing the occurrence of incidents or conditions that could lead to occupational injuries or illness. While it is Management's responsibility to provide a safe environment in which to work, the ultimate success of a safety and health program depends upon the full cooperation of each individual associate.

Safety should never be sacrificed for production. It must be considered an integral part of quality control, cost reduction and job efficiency. Every supervisor will be held accountable for

the safety performance demonstrated by the associates under their supervision. Our goal is the total elimination of accidents from our operations.

There are three sound reasons for this goal:

- No endeavor is worthy if it should cause human suffering through disabling injury or loss of life.
- A good safety record reflects the quality of management, supervision and the work force. It also serves to promote business and thereby contributes to the continuing growth and success of the Company.
- Poor accident experience increases costs, and results in a loss of profits. Our policy is to accomplish work in the safest possible manner consistent with good work practices. Management at every level is charged with the task of translating this policy into positive actions.

If an injury occurs on the job, no matter how minor, the supervisor is to be notified immediately so that appropriate medical treatment can be administered. As soon as possible thereafter, an Accident Report will be completed by the responsible supervisor.

Failure to report an accident immediately after it happens may result in dismissal and/or delay or denial of Workers' Compensation benefits.

All accidents and near accidents will be immediately investigated by the responsible project supervisor, the SURTREAT Health and Safety Director. Investigations will be conducted in accordance with the investigation format outlined in SURTREAT's accident investigation report (Attachment I – Safety Forms). Information will be obtained from witnesses, the first report of injury, the victim, and other sources, which may be available.

ATTACHMENT F - GENERAL SITE SAFETY RULES

GENERAL RULES

The following rules have been implemented to ensure SURTREAT's Project Goal of maintaining a safe and healthy work environment. Associates, subcontractors, and visitors shall be provided with a copy of these rules and are required to comply while on the SURTREAT project site. Associates are constantly being monitored for compliance with these rules and are recognized with incentives and awards for each project. ("Associate" as used in this Health & Safety Plan, refers to any SURTREAT employee.) The safety and security regulations of our customers must be strictly adhered to. This also applies to government standards and regulations. Anyone violating these rules shall be subject to disciplinary actions.

1. Tampering with or bypassing any safety device is prohibited.
2. Before setting up operations, locate the nearest phone, eyewash, emergency shower, and fire alarm.
3. Before setting up your operations, check the surrounding area for potential hazards and conflicts; overhead cranes, plant traffic, including railroads, workers in area, electrical wires, etc.
4. Report to work on time and in proper work attire, prepared to work in a safe and efficient manner.
5. Use or possession of narcotics, intoxicating substances, or guns and ammunition is prohibited.
6. NOTE: Supervisors must be notified if an associate is taking prescription drugs that may impair the associate's ability to perform certain job tasks (i.e. operating machinery, power tools, etc.)
7. Observe all posted warning signs (i.e. "Caution, Authorized Personnel Only," etc.) and respect project Site security. SURTREAT provides signs, barriers, and barricades wherever such protection is needed. If signs and barricades cannot provide adequate protection, particularly along a roadway, a flagman will be used.
8. Obey "NO SMOKING" signs. Smoke only in designated areas. Smoking and the use of open flames are strictly prohibited in areas where flammable liquids, gases, or highly combustible materials are stored, handled, or processed, and also in the decontamination or exclusion zones.
9. Unauthorized use of SURTREAT or client equipment is prohibited. Prior to each instance, obtain permission first, (i.e. to use hoists, powered apparatus, etc.)
10. Recording devices (cameras, camcorders, etc.) are not permitted without prior approval from the customer. If progress or finished construction photographs are desired, requests should be made through the SURTREAT representative and/or the customer representative and security.
11. Engaging in horseplay, running, or jumping of any obstacles is prohibited.
12. Other unsafe acts, such as jumping from a vehicle or structure, running or throwing objects, are prohibited.
13. SURTREAT Health & Safety Representatives are authorized to stop any work, which they may consider hazardous to associates or subcontractor personnel or equipment.
14. Inform your supervisor of any personnel or equipment problem immediately. This would include, but not be limited to, near misses, property damage, faulty or defective equipment, use of fire extinguisher, client requests or public concerns, etc.
15. Report any injury or incident to their supervisor, immediately, no matter how insignificant. Failure to

do so may result in a delay or denial of benefits you may otherwise be entitled to. A written report should follow as soon as possible but within 24 hours.

16. Prior to beginning work, associates will be instructed on emergency procedures to be followed. The supervisor is responsible for notifying the associates of emergency situations and the evacuation. In the event of an evacuation, do not go home or leave the work Site until released by your supervisor.
17. Areas sealed with polyethylene may become slick especially when disposable booties are worn - extra caution should be taken to secure footing and maintain proper balance during these situations.
18. Working from elevated platforms, scaffolding, and ladders can pose a great danger. Do not overreach, move ladder, scaffold or platform. Avoid shortcuts on scaffolding, ladders, and platforms. All provision of 29 CFR 1926 Subpart L must be complied with when working in or around platform, scaffolding, and ladders.
19. Good housekeeping procedures will be maintained during all project operations. Tools, materials, and equipment are more easily located and placed into service when good housekeeping procedures are followed.
20. Associates are prohibited from the unauthorized removal of any property or Company materials without the special authorization. Associates involved with theft of company property without authorization are subject to immediate termination. Associates involved in theft activities are also liable to the company for full restitution of monies and/or properties taken from SURTREAT, and are subject to criminal prosecution by the Company. Theft of Company property, client property, or personal property belonging to associates will not be tolerated, and violators will be prosecuted.
21. Associates are cautioned that the Company will not be responsible for loss of personal property due to theft. Associates are advised to leave jewelry items, valuables, and personal items in a locked and secured area away from the job Site.
22. Associates will wear all required personal safety protective equipment as required by SURTREAT, while inside or outside the containment areas or hot zones.
23. Associates, visitors, and subcontractors are required to be dressed in the proper work uniforms at all times as per the requirements of the job.
24. Associates will obtain proper authorization prior to leaving the job Site.
25. Safety guards, safety plugs, and/or any other electrical safety device shall not be bypassed, removed, or compromised in any way.
26. Step ladders, scaffolding, and/or platforms are to be used as designed and instructed by the supervisor. Stepladders should be used in the fully extended position only.
27. Respiratory equipment will be worn properly in accordance with OSHA AND OKINAWA rules.
28. Respiratory equipment will be kept clean and sanitary for reuse. Respirators not in use will be cleaned and stored in sealed protective bags.
29. Respirator cartridges new or used will be kept clean at all times. Cartridges that are spent should be properly discarded to prevent accidental re-use.
30. Optical eyewear other than industrial safety eyewear is prohibited from use on the job Site.
31. Safety belts and lanyards are to be worn properly when required.
32. Specific maintenance and service to equipment and/or tools is to be conducted only by skilled maintenance personnel. Equipment used at the Site will be inspected daily by a competent person.
33. Intentional violations of associate rights concerning health and physical well being will be cause for

termination. Willfully causing an accident and/or injury to ones self or to a fellow employee will be cause for immediate termination.

34. Hand tools are to be used for the specific purpose of their design. Hand tools, electrical tools, and mechanically operated tools are to be free obstructions.
35. Waste identification labels will not be applied to any material which does not correspond with label (i.e. hazardous waste labels).
36. All safety equipment and tools are to be inspected for defects routinely by each employee prior to use. Damaged tools or equipment must be reported immediately to a supervisor and taken out of service.
37. All job Site personnel must be aware of and know where to locate fire extinguishers and emergency evacuation routes.
38. Hand tools are not to be left on the floor, scaffolding, ledges, and/or ladders.
39. Extension type ladders should be used with a 1 to 4 ratio - one foot out for every four feet of elevation.
40. Ladder users will face the ladder while ascending and descending. The top and second to top steps are not to be used for standing. Only one person at a time on a ladder. Bracing on the back of the ladder should not be used for climbing. Ladders should be secured to a fixed object when possible.
41. Guardrails and toe boards should always be installed on scaffolding. Workers should be careful to keep all debris bagged and obstacles off the floor. All components such as cross braces, railing, pin connectors, planking, toe boards, or scaffold grade lumber should be available before the unit is assembled.
42. Mobile scaffolding base dimensions should be at least one-half of the height. Scaffolding ten feet high or higher must have rigid guardrails.
43. All electrical equipment used on the job Site will have electrical grounding devices with ground fault circuit interrupters. An extension cord without a ground wire plug is never to be used. Damaged electrical cords will be discarded or turned into the office for repair. All electrical cords and boxes are to be considered live until tested otherwise. Never spray water on or near open panels or electrical boxes. All 110v, 15-20 amp circuits must be protected with ground fault circuitry, or an assured grounding program. Electrical tools should be unplugged prior to servicing.
44. SURTREAT requires that an electrical lock out/tag out program be in effect at all job Sites. A written log entry will be made any time a lock out procedure goes into effect.
45. While preparing to do work around energized equipment such as transformers and/or electrical panel boxes, all aspects of 29 CR 1926 Subpart K must be complied with. Equipment that cannot be de-energized during the abatement will be covered and sealed on three sides only. There must be adequate ventilation to the panels and or boxes; or else there is the possibility and danger of explosion.

MOTOR VEHICLES

1. Any person operating a company vehicle must have a current, valid and appropriate driver's license. In addition, all applicants considered for positions, which include driving a company vehicle, will be subject to a Motor Vehicle Record search and evaluation.
2. All company vehicles must be equipped with a first aid kit at all times.
3. All company vehicles must be equipped with a fire extinguisher and flares or reflectors.
4. All company vehicles must be maintained in good mechanical condition. A pre-trip inspection shall be performed, and any defects or malfunctions must be reported to the supervisor before the vehicle leaves the yard.
5. The number of seat belts available for use shall limit the number of persons inside the vehicle.
6. The driver is responsible to see that he/she and each authorized passenger are properly wearing a seat belt while riding in a company vehicle.
7. All rules of the road and all customer regulations concerning vehicles must be obeyed.
8. Use extreme caution when backing a vehicle. If at all possible, use a safetyman to guide you.
9. All vehicles will be maintained in a clean and orderly manner to prevent injuries and fire hazards. This includes the cab as well as the inside and outside of the truck.
10. When your job assignment requires you to drive a company vehicle, you are considered to be a professional driver. Failure to drive courteously and to obey the rules of the road may result in the loss of this privilege and termination of your employment.
11. The use of company vehicles shall be restricted to the specific job to which you are assigned. Any unauthorized use will be cause for disciplinary action up to and including discharge.
12. All vehicles must be parked in authorized areas only.

MOTOR VEHICLE ACCIDENT REPORTING AND GENERAL LIABILITY

When an accident occurs, as soon as the preliminary investigation has been completed and the necessary claims handling actions have been taken (medical care for injured, rental cars obtained, etc.), the accident report must be filled out immediately. The vehicle operator, and / or equipment operator, and Field Project Manager are responsible for generating the accident report and initial investigation of the accident. The operator must immediately notify the supervisor of all equipment or vehicle damage. The accident report should be submitted to the **SURTREAT** Health & Safety Director.

In some states, the state and local law enforcement agencies require additional forms and paperwork. It is the driver's responsibility to obtain these forms and to submit the properly prepared reports on a timely basis, to these additional regulatory agencies.

Appendix I: Project Management Plan for CPC Project FAR-16

ARMY FACILITIES
CORROSION PREVENTION AND CONTROL PROJECT PLAN
Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

TRISERVICE PROGRAM
ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

15 June 2005

Submitted By:

Ashok Kumar

U. S. Army Engineer Research & Development Center (ERDC)
Construction Engineering Research Laboratory

Comm: 217-373-7235

____
(Project Number to be *assigned by OSD when approved*)

ARMY FACILITIES
CORROSION PREVENTION AND CONTROL PROJECT PLAN
Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

1. **STATEMENT OF NEED**

PROBLEM STATEMENT: Severe corrosion problems have been identified on the Gushikawa Bridge in Okinawa that provides access for the main fuel pipeline operations at Tori Air Station. This bridge runs parallel and upstream of the main fuel pipeline and is part of the access roadway allowing access to the various control valve boxes along the pipeline. The fuel pipeline provides diesel fuel for vehicle, aircraft and Navy ships. Moisture and chlorides from the coastal atmosphere have infiltrated the concrete and caused the steel rebar in concrete to corrode. As the steel corroded the corrosion products expand, and caused the concrete to spall off. A horizontal section of a beam beneath the bridge is shown in Figure 1.

IMPACT STATEMENT: If this project is not funded, the fuel supply to vehicles, aircraft and Navy vessels will be in jeopardy, as the rebar in the concrete bridge will continue to corrode. The corrosion products will swell and cause the concrete to spall off, resulting in weakening of the bridge to the point that it will eventually become unusable, and have to be replaced. Support operations for providing fuel to all vehicles, aircraft, and Navy vessels will not be available when needed, thus impacting transport and mobility. The result is an unsafe structure for drivers that must cross the bridge, in addition to wasted time due to traffic delays during maintenance and rerouting of traffic due to necessary maintenance.

2. **PROPOSED SOLUTION**

TECHNICAL DESCRIPTION:
Corrosion protection for the rebar can be established through the use of a zinc-rich cathodic protection compound that can be applied to the concrete deck. The phenomenon of "sacrificial" cathodic protection is based on the ability of a more active metal, such as zinc to easily loose electrons when electrically connected to steel rebar, while an ionic current flows via moisture through the pores of the concrete. This establishes an electrochemical reaction that results in the steel rebar becoming the *cathode*, while the zinc-rich coating becomes the *anode,* and is "sacrificed," and slowly oxidizes over many years. In this case, the rebar is said to be *cathodically protected.*

The new technology relies on the use of a liquid that is applied like paint to the surface of a structure such as a bridge deck, providing galvanic protection of embedded steel rebar for existing structures by suppressing corrosion in carbonated and chloride contaminated concrete, thus extending the life of the structure. The new technology is a three-

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component moisture cured metallic zinc-rich coating. The coating compound can be sprayed, brushed or rolled onto the concrete surface. For example, in the case of the bridge support beam component in Fig. 1, the damaged areas must first be rehabilitated with new concrete and then coated with the cathodic protection compound. The zinc-rich coating is then connected to the steel rebar by wires, and will act as a sacrificial (or "galvanic") anode. See Fig.2.

The technology described for corrosion prevention of rebar was developed and tested by NASA in 2002 to protect steel within the concrete infrastructure at NASA's Kennedy Space Center, which has a corrosive coastal environment similar to Okinawa.

The cathodic protection compound can be applied to uneven surfaces and to the underside of structures. It is recommended for bridges, parking decks, ramps, garages, concrete piers, offshore platforms, piles, pillars, pipes, buildings, foundations and underside application to structures of many sizes and shapes. One gallon is used for 160 sq. ft of the concrete structure.

Technology Maturity

The use of a sacrificial galvanic anode for corrosion protection that can be applied to a bridge deck like paint represents a new that has only recently been field tested.

This sacrificial anode cathodic protection compound has been applied successfully by the St. Paul, MN Traffic Department on a 30 year old bridge (Fig. 2). It was applied to the underside of the bridge deck by rolling. The project included sandblasting, excavating to connect the rebar and to assess the condition and wiring system. A system was put into place to take corrosion protection readings, visible in Fig.2 as small junction box. The almost invisible current collecting wires connecting the coating to the rebar are highlighted. Part of the insulated current return wire to the rebars is visible over the pier arch.

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CORROSION PREVENTION AND CONTROL PROJECT PLAN
Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

Figure 1. Corroded Rebar in horizontal beam underneath Gushikawa Patrol Bridge in Okinawa with failing rebar in concrete.

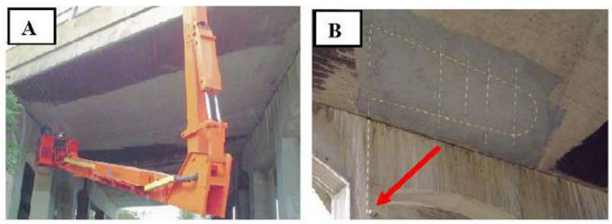

Figure 2. A: Example of galvanizing compound being applied under bridge deck; B: Galvanizing compound applied with current collecting wires highlighted; small junction box is visible (arrow) (St. Paul, MN Bridge Deck).

Reviewer's Comment: "Rewrite to Strengthen"

The technology described for corrosion prevention of rebar was developed and tested by NASA in 2002 to protect steel within the concrete infrastructure at NASA's Kennedy Space Center, which has a corrosive coastal environment similar to Okinawa. The technology relies on a zinc-rich cathodic protection coating, which was field tested by the St. Paul, MN Traffic Dept.

The zinc-rich urethane coating contains particles of magnesium and indium, as well as moisture-attracting compounds that facilitate the protection process. It is applied easily by spraying, brushing, or rolling, and is particularly suited to applications such as bridges, decks, ramps, concrete piers, offshore platforms, and foundations. The coating also can be applied to uneven surfaces and to the underside of structures, as well as to vertical, horizontal, and overhead surfaces, and to structures of many shapes.

RISK ANALYSIS: The risk for this project is low, as a mature technology for protection of the rebar will be employed. The implementation of technologies will not be performed in phases.

EXPECTED DELIVERABLES AND RESULTS/OUTCOMES:
The expected results of the application of these cathodic protection compounds are extension of the life of the reinforced concrete structure, as well as increase safety.

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CORROSION PREVENTION AND CONTROL PROJECT PLAN
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PROGRAM MANAGEMENT
The Project Manager will be: Dr. Ashok Kumar (ERDC/CERL). The Associate Project Manager will be Dr. L. D. Stephenson (ERDC-CERL). Mr. Martin Savoie is Chief of the ERDC/CERL Materials and Structures Branch. The stakeholders will be Mr. James Leander (Okinawa Area Directorate of Public Works POC), Mr. Alan Carroll (IMA-PARO, Mr. Paul Volkman (HQ-IMA), Mr. David Purcell, (HQ-ACSIM), as well as Triservices WIPT representatives, Ms. Nancy Coleal (AFCESA/CESM), and Mr. Tom Tehada (NFESC).

The customer is Mr. James Leander (Okinawa Area Directorate of Public Works POC). The Army has provided matching funds for this project through HQ-IMA (See Memorandum from ACSIM Director for Facilities and Housing in Appendix 2). Coordination with the Army Corrosion Program Office will be through Mr. Hilton Mills (AMC).

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation. The approach for project performance will include use of Type I –In house, organic capabilities, and Type II Existing Contacts. A Type II Existing Contractual Agreement is expected to be utilized for this project two months after receipt of funds.

3. **COST/BENEFITS ANALYSIS**

a. **Funding ($K):**

Funding Source	**OSD**	**Service Matching**
Labor	290	300
Materials	120	120
Travel	40	40
Report	30	30
Air Force/Navy Participation	10	-
TOTAL ($K)	**490**	**490**

b. **Return-On-Investment Computation**

1) Useful Life Savings (ULS) is equal to the "Net Present Value (NPV) of Benefits and Savings" calculated from the Spreadsheet shown in Appendix 1 that is based on Appendix B of OMB Circular A94.

ULS= $ 12,637K (from OMB Spreadsheet in Appendix 1. Assumptions for this calculation are also given in Appendix 1).

ARMY FACILITIES
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2) Project Cost (PC) is shown as "Investment Required" in OMB Spreadsheet in Appendix 1; **PC= $980K**.

$$ROI = \frac{ULS}{PC} = \frac{\$12{,}637K}{\$980K} = 12.9$$

c. **Mission Criticality:** The benefits of the implementing advanced corrosion resistant materials selection corrosion control technologies at the potable water treatment plant and the wastewater treatment plants include restoration of the plant to its optimum operating condition, in addition to reduced maintenance, and increased safety, increased operational readiness and reliability.

4. **SCHEDULE**

MILESTONE CHART

EVENT	TIME (months after receipt of funds)
Award Contract	2
Implement Galvanic Protection Compound	4
Complete implementation of galvanic protection compound	16
Complete Documentation (includes Final Report, Procurement Specification, Ad Fliers	18
Complete ROI Validation	18

a. Note: If project is approved, *bi-monthly status report will be requirement* (i.e. starting the first week of the second month after contract award and every two months thereafter until final report is completed). This report will be submitted to the DoD CPC Policy & Oversight office. The report will include project number, progress summary (and/or any issues), performance goals and metrics and upcoming events.

b. Examples of performance goals and metrics: include achieving specific milestones, showing positive trend toward achieving the forecasted ROI, reaching specific performance quality levels, meeting test and evaluation parameters, or successfully demonstrating a new system prototype.

ARMY FACILITIES
CORROSION PREVENTION AND CONTROL PROJECT PLAN
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5. IMPLEMENTATION

a. Transportability/Transition approach. Where appropriate, Unified Facilities Guide Specifications (UFGS), Engineering Instructions (EI), Technical Instructions (TI), and Technical Manuals (TM), including updates, will be developed. In addition, a final report describing the details and results of the project, will be submitted to OSD. The draft documents will be posted on the OSD Corrosion Exchange website under "Spec & Standards" and "Facilities Special Interest Group (SIG)." Coordination with potential users will be an essential part of the transition of the technology.

It is the intent of the Project Management Plan (PMP) to implement this corrosion prevention and control technology at multiple regions and installations. The UFGS, EIs, TIs, and TMs, including updates to existing guidance documents, developed for Army-wide implementation during the FY06 project, will be utilized to facilitate the planned implementation of corrosion resistant materials for rebar.

b. Potential ROI validation. The potential ROI will be validated by comparison of. the performance of the structure with the galvanic compound versus performance of the bridge without the galvanic protection compound.

c. Final Report: A final report will be submitted within 60 days of completion of the project. The report will reflect the project plan format as implemented and will include lessons learned.

Projected Benefits:
Based on the past record of these technologies in commercial applications, it is expected that the use of these galvanic coatings will prevent corrosion of rebar in the bridge.

Operational Readiness
These coating technologies are commercially available and ready for implementation as solutions to corrosion of rebar in bridge decks and other reinforced concrete structures.

Management Support
This project enjoys the support of the Okinawa Directorate of Public works (DPW) Office, **Moreover, the Army (HQ-IMA) has planned to provide matching funds for FY06. See attached Memorandum from ACSIM Director for Facilities and Housing in Appendix 2.**

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

6. COORDINATION SHEET

ORGANIZATION	SIGNATURE	DATE
Project Manager	Ashok Kumar	6/13/05
ERDC/CERL Branch Chief	[illegible]	6-13-05
Installation DPW POC	/s/	12 June 05
IMA Region	/s/	28 Sep 05
HQ IMA	/s/	15 Jun 05
HQ ACSIM	/s/	15 Jun 05
HQ AMC	[illegible]	23 Sept 05
Tri Service Facilities WIPT Chair	/s/	15 June 05

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

6. COORDINATION SHEET

ORGANIZATION	SIGNATURE	DATE
Project Manager		
ERDC/CERL Branch Chief		
Installation DPW POC	[signature]	12 June 05
IMA Region		
HQ IMA		
HQ ACSIM		
HQ AMC		
Tri Service Facilities WIPT Chair		

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

6. **COORDINATION SHEET**

ORGANIZATION	SIGNATURE	DATE
Project Manager		
ERDC/CERL Branch Chief		
Installation DPW POC		
IMA Region	Wayne Ursh	9/28/05
HQ IMA		
HQ ACSIM		
HQ AMC		
Tri Service Facilities WIPT Chair		

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

6. COORDINATION SHEET

ORGANIZATION	SIGNATURE	DATE
Project Manager		
ERDC/CERL Branch Chief		
Installation DPW POC		
IMA Region		
HQ IMA	[signature]	6/1/05
HQ ACSIM		
HQ AMC		
Tri Service Facilities WIPT Chair		

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

6. COORDINATION SHEET

ORGANIZATION	SIGNATURE	DATE
Project Manager		
ERDC/CERL Branch Chief		
Installation DPW POC		
IMA Region		
HQ IMA		
HQ ACSIM	A. Purcell	15 Jun 05
HQ AMC		
Tri Service Facilities WIPT Chair		

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

6. COORDINATION SHEET

ORGANIZATION	SIGNATURE	DATE
Project Manager		
ERDC/CERL Branch Chief		
Installation DPW POC		
IMA Region		
HQ IMA		
HQ ACSIM		
HQ AMC		
Tri Service Facilities WIPT Chair	Thomas Tehada	6/15/05

This is a TriService Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT PLAN

Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

7. APPENDICES

Appendix 1. Return On Investment (ROI) Calculations

Assumptions:

Alternative 1: The existing bridge will need maintenance from year 1 to year 13 at a cost of $40K to $52K. The bridge will be replaced in year 14 at a cost of $30.5M. The new bridge will utilize the galvanic protection compound described herein at a materials cost of $240K. The total cost will be $30.74M in year 14, as shown under Baseline Costs in ROI Spreadsheet (Appendix 1a).

Additional costs of $54K, will be incurred from year 1 to year 13 due to increased travel time and delays in fuel service operations to which the bridge provides access, while portions of the bridge are shut down for maintenance, as shown in ROI Spreadsheet (Appendix 1) under *New System Benefits/Savings*.

Alternative 2: Applying the galvanic protection compound to the bridge deck to protect the rebar from corrosion at an investment of $980K, results in life extension of the bridge, as well as reduced maintenance. The galvanic protection system will require annual operation and maintenance costs of $15K, shown under *New System Costs* in the ROI Spreadsheet for years 1 to year 13. The additional costs due to bridge downtime will be avoided. After Year 14, the maintenance costs are the same, so no further analysis is needed.

Comparing the two alternatives, the return-on-investment for Alternative 2 is 12.9.

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Appendix 1a.

Return on Investment Calculation

Investment Required			980,000
Return on Investment Ratio	12.89	Percent	1289%
Net Present Value of Costs and Benefits/Savings	125,363	12,762,154	12,636,792

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	40,000		15,000	54,000	14,019	87,852	73,833
2	40,000		15,000	54,000	13,101	82,100	68,999
3	45,000		15,000	54,000	12,245	80,814	68,569
4	45,000		15,000	54,000	11,444	75,527	64,084
5	46,000		15,000	54,000	10,695	71,300	60,605
6	50,000		15,000	54,000	9,995	69,295	59,301
7	50,000		15,000	54,000	9,341	64,761	55,420
8	50,000		15,000	54,000	8,730	60,528	51,798
9	50,000		15,000	54,000	8,159	56,566	48,407
10	50,000		15,000	54,000	7,625	52,863	45,239
11	50,000		15,000	54,000	7,127	49,410	42,284
12	50,000		15,000	54,000	6,660	46,176	39,516
13	52,000		15,000	54,000	6,225	43,990	37,765
14	30,740,000					11,920,972	11,920,972
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ARMY FACILITIES
CORROSION PREVENTION AND CONTROL PROJECT PLAN
Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa (O&M, FY06)

Appendix 2

DEPARTMENT OF THE ARMY
ASSISTANT CHIEF OF STAFF FOR INSTALLATION MANAGEMENT
600 ARMY PENTAGON
WASHINGTON DC 20310-0600

25 MAR 2005

DAIM-FD S: 15 Oct 2005

MEMORANDUM FOR DIRECTOR, INSTALLATION MANAGEMENT AGENCY, 2511 JEFFERSON DAVIS HIGHWAY, ARLINGTON VA 22202-3926

SUBJECT: FY 06 Army Corrosion Control Program

1. OSD has tentatively allocated a total of $15.0M in FY 06 matching funds for implementation of corrosion prevention and control projects for equipment and facilities. The enclosed list of Army projects, totaling $13.3M, will be presented for approval to OSD in April 05.

2. The Army programming target is not less than $10.0M of facility related projects in an effort to obtain a minimum of $5.0M of the OSD matching funds. To participate in OSD's funding augumentation, HQIMA will reserve $5.0M in FY06 OMA funds, to be released to ERDC-CERL upon confirmation by this office that OSD matching funds are available. Further instructions on the actual distribution of funds will follow at that time.

3. POC for this action is Mr. David N. Purcell, or (703) 601-0371, David.Purcell@hqda.army.mil.

4. Quality Facilities for Quality Soldiers!

FOR THE ASSISTANT CHIEF OF STAFF FOR INSTALLATION MANAGEMENT:

Encl
as

MARK A. LORING
Colonel, GS
Director, Facilities and Housing

CF:
DACSIM

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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August 2009	Final	

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Corrosion Prevention of Rebar in Concrete in Critical Facilities Located in Coastal Environments at Okinawa

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
Corrosion Prevention and Control

6. AUTHOR(S)
L.D. Stephenson, Ashok Kumar, Robert Walde, and Max Merzlikin

5d. PROJECT NUMBER
CPC FAR-16

5e. TASK NUMBER
MIPR6FCERB1020, MIPR6H6AG3CPC1

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-09-27

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Installation Management Command
Engineering Office, Directorate of Public Works (IMPW-E)
2511 Jefferson Davis Hwy.
Arlington, VA 22202

10. SPONSOR/MONITOR'S ACRONYM(S)
IMCOM

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14. ABSTRACT
The corrosion of steel rebar in reinforced concrete structures is a pervasive and expensive problem for the Department of Defense. The maintenance and repair costs for affected structures and equipment amounts to hundreds of millions of dollars each year, and the degradation negatively impacts military readiness and infrastructure safety. This report documents a demonstration of a concrete rebar corrosion inhibitor system and a liquid galvanic coating that provides cathodic protection for steel-reinforced concrete. These treatments were applied to critical infrastructure in a highly corrosive environment located at U.S. military facilities in Okinawa, specifically, two portions of a wall ring girder in a warehouse at Naha Military Port and two culvert bridges at the Kadena Air Force Base fuel storage depot.

The data obtained in this demonstration show quantitatively that the corrosion inhibitor application significantly reduced the corrosion rate of the rebar on the tested structures. The galvanic coating appears to be providing protection to the rebar, but quantifying the extent of protection or positive impact on service life would require further monitoring and evaluation.

15. SUBJECT TERMS
Okinawa military installations, corrosion prevention and control, reinforced concrete repair, steel rebar, liquid galvanic coatings, corrosion inhibitor systems

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